Energy Conservation Study at Inland Container Depot, Tughlakabad, New Delhi

Prepared for Container Corporation of India Ltd, New Delhi

TERI Project Report No. 2002IE69

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We greatly acknowledge the support of entire maintenance and engineering staff of the depot in completing the field measurements during energy audit.

Executive summary

At the instance of Container Corporation of India Ltd (CCIL), Tughlakabad, New Delhi, a comprehensive energy conservation study was carried out by TERI, New Delhi. The main aim of the energy conservation study was to make detailed study of the utility areas, identify potential areas of energy conservation and recommend energy savings measures along with cost benefit analysis of the same. The executive summary highlights the major findings and recommendations of the energy audit.

The energy audit study covers the following systems to identify energy conservation opportunities.

- Rail mounted gantry cranes
- Transformers
- Demand management and power factor
- Lighting systems
- Diesel generating (small, large moving and medium stationary) sets
- Pumps
- Compressed air system
- Air-conditioning systems

The main report contains detailed analysis and recommendations emerging from the study of the unit. A summary of the major recommendations has been given in the following sections.

Rail mounted gantry cranes

The RMGs constitute about 7.8 percent of the annual electricity consumption

- Maximum load during the period of measurements was found to be 130 kW for RMG-1 and 75kW for RMG-2. It should be noted here that the peak load would vary depending on the weight of containers handled
- Both RMG showed very rapid variation of instantaneous power factor, RMG-1 showed a wider variation in power factor

Transformers

Depot receives electric power from BSES at 11kV. The power supply at 11kV is further stepped down to 433V through 8 distribution transformers and is supplied to different load centres in the plant.

- Operating efficiency of transformers were varying from 94.85% to 98.57%
- Lighting and refer transformers should be coupled together by a common bus with a bus coupling arrangement for improved reliability and optimisation of energy.

Demand management and Power factor

The average monthly power factor of the plant varied from 0.87 to 0.92 from June 2002 to January 2003.

- Reduction of contract demand to 2000kVA would lead to an annual saving of around Rs 2.4 Lacs
- It is recommended to improve the power factor by augmenting capacities of installed banks and improving switching of the installed banks
- Annual saving for three different average power factors have been calculated. It is clear that a maximum annual savings of Rs 9.5 lacs, Rs 13.5 lacs and Rs 17.4 lacs is possible by maintaining a power factor of 0.94, 0.96 and 0.98. This would require an investment of around Rs 8.0 lacs

Lighting systems

Existing lighting systems at CONCOR TKD. can be divided in to three groups mainly office or indoor lighting, warehouse lighting or industrial lighting and high mast tower lighting or floodlighting of areas.

- The connected lighting system loads at CONCOR TKD. is approximately 578 kW out of which 24 % is office or indoor load, warehouses load is around 23%, tower light accounts for 45% and remaining 7% are of workshop, water tank etc. lighting.
- The total estimated annual consumption in lighting system is approximately 1917031 kWh or 2130035 kVAh. Office lighting accounts for 22%, warehouse lighting for 23% and high-mast tower lighting consumes 48% of the total energy consumption in lighting system.
- Ordinary type fluorescent lamps are being used for office lighting which are not very energy efficient and high pressure sodium vapour lamps are predominantly used for warehouse & high-mat tower lighting which are very efficient source of light

- Approximately 12% fluorescent lamps were found faulty, 39% lamps in HMT lighting were not operating and 21% lamps in warehouse lighting were fused. Since when the lamp gets fused it does not give any light but the ballast remains in the circuit and accounts for power loss. If this scenario of faulty lamps would continue at CONCOR it would lead to wastage of 62275 Units of Rs 3.0 lacs annually.
- Measured lighting levels were less than the recommended lighting levels in office areas while levels were adequate only in few areas such as rail yard, ware houses and near HM Tower. However, there was hardly any illumination between the empty stacks, between empty stack & stack-3, between stack-3 & stack-2, between stack-2 & stack-1. This needs to be corrected.
- Timers are installed on HMT lighting and they switch on/off lights within 1 and half-hours but their performance is far from satisfactory.
- Replacement of existing electromagnetic ballast with super low loss ballast in all existing fluorescent fixtures could save approximately 70435 kVAh or Rs 2.81 lacs per year. This will require an initial investment of Rs 7.92 lacs with a simple payback of 2.8 years.
- Replacing existing electromagnetic ballast with electronic ballast in all existing fluorescent fixtures would yield annual savings of 83641 kVAh or Rs 3.33 lacs. An initial investment of Rs 22.5 lacs would be required with a simple payback of 2.9 years
- Replacing existing fluorescent lamps with T-5 lamps would save approximately 206902 kVAh or Rs 8.25 lacs per year but this would require an investment of Rs 9.62 lacs initially and the payback would be around 2.7 years.
- Existing timers which are not operating very satisfactorily could be replaced with timers with infra-red operated switches. This would help save approximately 106118 kVAh or Rs 4.23 lacs annually. An investment of Rs 3.15 lacs with payback of9 months would be required.
- Installation of energy saving device on HMT fixtures, which can operate HMT light at reduced wattage for six hours a day, could save197689 kVAh or Rs 7.88 lacs per annum. An investment of Rs 6.54 lacs would be required initially with a payback period of 10 months.
- By installation of microprocessor controlled luminous flux controller (Stabilux) on warehouse lighting 112420 kVAh or Rs 4.48 lacs could be saved annually. This type of controller being manufactured by EREM Italy

and got to be imported. The initial cost would be Rs 19 lacs with simple payback period of 4.24 years.

Diesel generating (small, large moving and medium stationary) sets

There are sixteen small, four large moving diesel generating (DG) sets and two medium stationary DG sets in the depot. The rated capacity of the individual small, medium and large set is 140 kVA, 625 kVA and 920 kVA respectively. The average engine load in the groups of small, medium set is about 55.0 percent (without capacitors), 62.3 percent (with capacitors) in Power pack no. 8 & 61.1 percent and 47.5 percent respectively. The engine load in RTGC mounted large sets is varying at rapid rate, wide range depending on the container weight during hoisting and trolleying operation.

- Irrespective of the number of DG sets in operation, the sets should be loaded to the optimum level (80 percent). This will ensure the best operating condition of the sets.
- It is recommended to perform the Specific Energy Generation Ratio (SEGR) test of the DG sets. The actual SEGR of the sets should be close to the designed level recommended by the manufactures.

Pumps

- Pumps consume about 2.5% of the total annual electricity consumption
- Flow of booster pumps had dropped to 25m3/Hr compared to initial flow of around 37.6M3/HR. Therefore, improving delivery of the pump by replacing it with a new pump would reduce electricity consumption by 4320 (Rs 16848) with an investment of about Rs 30,000.

Compressed air systems

There are four numbers of reciprocating type air compressors operating in the containers handling depot. Two identical big size compressors are installed at the side of railway track by the Indian Railway management. Free air delivery test was performed on four reciprocating compressors (No. #1, #2, #3 and #4). The free air delivery for compressor #1, #2 and #3 is found to be well below where as the same of compressor#4 is slightly below the satisfactory level. It is, therefore, recommended to get the four compressors overhauled to have better productivity and lower energy consumption.

- The leakage test, to quantify the leakages in the 30 metres distribution lines of rake testing was carried out. The leakage rate in the compressed air line is calculated to be 9%.
  By plugging these leakages, there would be an annual electrical energy saving of 6266 kWh. The corresponding monetary saving would be Rs 24000.
- Temperature of the air supplied to the suction of compressor #1 and #4 should be monitored periodically to ensure that it is, at least, equal to the ambient temperature. In case any rise is observed, the inlet air duct can be relocated.
- It was observed that two air receivers drain valve was manually operated to facilitate the water drainage. This provision not only passes the water but also allow the compressed air to pass to the atmosphere intermittently. It is recommended to use automatic drain valve to reduce the wastage of compressed air.

Air-conditioning systems

About 44 window air-conditioners were tested which represents approximately 10% of the total window air-conditioners installed in the depot.

- The average operating specific energy consumption of the window air-conditioners is found to be 1.53 kW/TR as against the rated specific energy consumption of 1.30 kW/TR.

Summary of Recommendations

Sl. No.	Suggested measure	Total annual savings (Rs Lacs)	Investment (Rs Lacs)	Payback period (years/months)
1	Reduce generation pressure of compressor			
	No. 1	0.038	Nil	Immediate
	No. 4	0.07	Nil	Immediate
2.	Plugging of compressed air leakages	0.24	Negligible	Immediate
3.	Optimization of drain interval in DG sets (small, large moving type & medium stationary type) for lube oil (using test kit)	--	0.35	--
4.	Increasing average SEGR 0.1 kWh/L in			
	set #1	0.056	Nil	Immediate
	set #2	0.045	Nil	Immediate
5.	Insulating exhaust pipes with asbestos rope, reducing air temperature through adjacent filter in small (140 kVA) DG sets	Moderate	Negligible	Immediate
6.	Savings due to Power factor improvement	13.5	8.0	Less than 1 year
7.	Optimisation of contract demand	2.4	Nil	Immediate
8.	Improvement of pumping capacity	0.16	0.30	1.8 years
9.	Replacement of choke with SLL ballast	2.8	7.92	2.82 years
10.	Replacement of choke with electronic choke	3.33	9.62	2.88 years
11.	Replacement of tube lights with T-5 lamps	8.25*	22.45*	2.72 years
12.	Replace timers in HMTL with Energy Pack	4.23	3.15	9 months
13.	Install Trend Setter on HMTL fixtures	7.89*	6.54*	10 months
14	Install Stabilux HMT lighting	8.92	41.0	4.6 years
15.	Install stability on warehouse lighting	4.48*	19.0*	4.24 years
	Total	42.86	74.18	

* Considered in total savings and investment

1

Introduction

Comprehensive energy audit of the inland container depot of Container Corporation of India Limited (CCIL), Tuglakabad Unit, at New Delhi was carried out by TERI, New Delhi, to study the operating efficiency of major energy consuming systems and to identify the energy saving possibilities. TERI team visited the depot between January-February 2003 to undertake extensive measurements and for collection of data. Discussions were also held with the depot personnel to accomplish the task in the meaningful manner. Depot personnel asked for recommendation/ information on focussed energy conservation measures and strategy formulation to achieve that at site. These conservation measures can be in the following three categories: (1) Measures with negligible investment, (2) Measures with minimum investment, (3) Measures with higher investment.

The inland containers handling depot is the central link in the export chain between the land-based delivery of the containers (ordinary and refrigerated type) and the port. Container Corporation of India Limited (CCIL) is a leading company for handling of inland containers. The inland container depot in New Delhi is one of the rapidly growing and continuous handling container depots in the country. The basic/ main functions of the depot are the following. (a) Discharging (from the depot) loaded & unloaded containers to carriers, (b) Receiving containers (loaded & unloaded) from trucks, (c) Arranging loaded containers at yard, (d) Storing containers temporarily to account for the difference in arrival times of the loaded and unloaded carriers, (e) Testing of wagon before loaded containers placement, (f) Maintenance of refrigerated containers and other utility equipment in the depot. Containers can be stacked up to three high and up to five rows wide with a line. Various types of container handling systems operate for 24 hours in the yard. The cranes are used for the movement of containers from empty stock to the delivery centre for packaging, packed containers to the container stock and railway wagon as well as others. The yard is like an open air handling facility for the mobile installation for horizontal and vertical movement of container, which operates three shifts round the clock every day of the year. The movement of the handling systems upto the railway track is a must. So heavy-duty systems/ cranes are used for handling container at the final stage. The size of the containers in this depot is 20 ft and 40 ft. The typical container height is 8 ft 6 inches. The standard width of containers is 8 ft. The containers handling depot has two railway tracks and roads with two kinds of overhead cranes (rail mounted gantry type, RMGC & rubber tyred gantry type, RTGC) for similar purpose. The cranes are used for handling containers load between 20-40 MT at any instant. The average number of moves of the individual RMGC, RTGC for variety of goods in containers were 222 moves/ day and 175 moves/ day for the last 6-12 months period. The productivity gains in the depot depend on the improvement in the mix of factors including operating practice, operators skill, systems, equipment, as well as external factors such as incoming truck scheduling and yard space constraints.

Each RTGC is consists of one in-built diesel engine, four tubeless tyres and one fuel tank. The individual RTGC has in-built engine, alternator system placed above ground at a height of about 2.5 metres to provide power (electricity) for lifting operation and it consists of one circular pipe carrying hot flue gases. The flue gases is discharged at one corner of the crane and well below the overhead trolley level. The individual crane (RMGC/ RTGC) is handling loaded (fully or partially) containers to lift from two sides of each track and to properly place them on the empty wagon at the centre. The loaded (fully or partially) containers are handled by switching over to the smaller sized RT cranes to bring them from distant to close position (sides) of the track after observing adequate clearance. The load on the large sized individual crane is reduced marginally since the RTGC installation. The high productivity of the gantry cranes is required to gain a significant reduction of the time in depot for the containers. Normally, one reciprocating air compressor is in operating condition and other as stand by for the period of about last 1 year. There are two mobile RTR systems used for the pneumatic testing of empty wagons on the railway tracks. The management has been trying to upgrade the existing depot facilities with the state-of-the-art techniques. The average installed capacity of each of the four RTGCs and two RMGCs is 40 MT per lift. The major fuel being used by the depot is HSD. There are two sources of power supply to the depot – BSES Rajdhani Power Limited supply and the depot's own generation through diesel generator sets.

Depot management also asked for undertaking the assignment of energy conservation study in the proposed areas, appropriate addresses/ data/

information and systematic implementation strategy of saving measures. The study also includes the following areas for higher energy efficiency in the depot:

- RMGCs improved utilisation and their empty container handling/ movement minimisation,
- Lighting systems improved utilisation, the illumination level and energy consumption,
- Ways for minimizing waste energy in all equipments,
- Suppliers address of suitable type newly designed or energy efficient equipment/ system/ component,
- Presentations on the analysis, results and recommendations,
- Active support in the implementation of measures,
- Review meeting to monitor progress of implementation.

The systematic checks on two RMGCs operation at normal and peak/ heavy load condition in included in the study to establish the guideline for average savings/ target for their extensive service most of the time throughout the year. The operating practice for saving valuable energy and taking care of all problems related with the upkeep of the energy efficiency of all existing/ conventional equipments will be studied.

The focus of the present study was to carry out a detailed analysis of the major energy consuming equipments as given in the proposal submitted by TERI. Effort with conventional and modified practice was made to operate the existing individual equipment/ system at different depot load in number of days. Implementation of several house-keeping measures were also initiated at site after the extensive measurement. A report covering each of these areas is given in the following chapters.

2

Rail Mounted Gantry Cranes

The RMGCs constitute about 7.8 percent of the annual electricity consumption. The plant has installed two RMGCs for loading and unloading containers from the railway wagon. The power supply from the 11kV bus is stepped down to 3.3kV by two dedicated transformers (of 630kVA) which feeds RMGCs-1 and 2. The supply at 3.3kV is further stepped down to 415V. RMGC-1 essentially has DC drives while RMGC-2 has AC drives to operate different equipment's of the cranes. Details of the RMGC are given in table2.0.

Table 2.0 Details of RMGC

Technical data	
Lifting capacity	
Rated load under spreader	40 tons
Lifting height	9.500 m
Gantry rail span	22.50 m
Outreach on both sides	7.000 m
Hoisting speeds	
With rated load	20 m/min
With empty spreader	40 m/min
Trolley travel speed	75.0 m/min
Gantry travel speed	
With rated load	25 0 m/min
Empty spreader	90.0 m/min
Capacity below spreader	40 t
Height of lift below spreader	9.5 m
Container stacking height	1 over 2
Total trolley travel path	25.57 m
Trolley travel on over-hung side	7.0 m
LT wheel gauge (span)	22.5 m
LT wheel centres	17.0 m
Over-buffer dimensions of crane	21.75 m
Rail to rail height	14.0 m
Trolley gauge	7.2 m
Trolley wheel base	6.06 m
Slew track diameter	5.36 m CRS.
Slewing range	± (180° + 5°)

Speeds	
Long travels	75 m/min
Cross travels	50 m/min
Slew motions	0.9 rpm/0.15 rpm
Hoist	15 m/min (with load) 30 m/min (without load)

Wheel dia on treads	
Long travels	16 nos 630 mm
Cross travels	4 nos. 630 mm
Slew	4 nos. 500 mm

Rail sizes	
Long travels	CR-80
Cross travels	63 Sq. bar
Slew paths	63 Sq. bar

Travel length of crane	700 m
Max. operating wind speed	24 km/hr

Current collections	
On trolleys	Festoon system
On crane	Cable reeling drum
Supplies	3.3 kV, 50 C/s. A.C.
Ambient temp	45°C

Motor details

Hoists
2 x 65 kW, 200 V, 368 A. Cont., Gear box ratio: 72.3:1 - 13/26 rpm, 935/1870 rpm, DC Shunt, IP-23, KEC, Frame - KLDC-200LX (special), Lot No.920220 - 01 & 02.
Long travels
4 x 25 kW, 400 V. 70A, 1000 rpm, DC shunt, IP-23 KEC, Frame - KLDC-180 SX (special), Lot No.920 219-01, 02, 03 & 04.
Cross travels
2 x 15 kW, 200 V, 85.5 A. cont., 1600 rpm, DC shunt, IP-23, KEC, Frame - KLDC 132 MX. 62:1 gear box ratio.
Slew drives
0.4/2.4 kW, 2.3/6.0 A, 1.6/9.8 rpm, AC Sq. Cage, Dual speed.
Spreader details

Drive motors	7.5 kW
Working pressure	150 bar
Gear pump capacity	38 1/min

Maintenance crane	2 t capacity electric hoist

Wire rope details

Hoists
26 mm. Dia., 6 x 36 const., steel core, galvanized, ordinary lay, 1770 N/mm² tensile, 427 KN breaking load as per IS.2266-1977. Right hand and left hand.
Anit sway
11 mm dia, non-rotating, 18/7 or 17/7 constn., fibre core, ordinary lay, galvanised, 1770 N/mm², right hand, 68 KN breaking load as per IS:2266-1977.

RMGC being power intensive equipment has a large bearing on the peak load on the system. Therefore a detailed study of the instantaneous power consumption was studied. Different operations of the cranes like trolley, hoisting, grantry, etc was studied. It was generally seen that the maximum load for both the RMGCs was during hoisting operations. Since load variation during hoisting operations was quite fast Data loggers was installed on the HT side of the transformers for both the RMGCs to record the variation in the instantaneous consumption. Data obtained for such exercise are given in figure 2a and figure 2b.

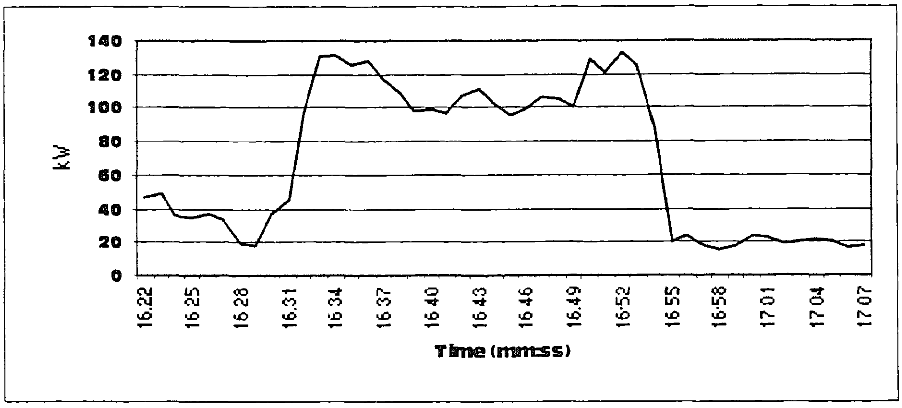


Figure 2a Variation of instantaneous power (RMGC - 1)

It is clear from the figure that maximum load during the period of measurements was 130 kW for RMGC-1. Similar logging was carried out for RMGC-2 and it was observed that maximum load for RMGC-2 75kW. It should be noted here that the peak load would vary depending on the weight of

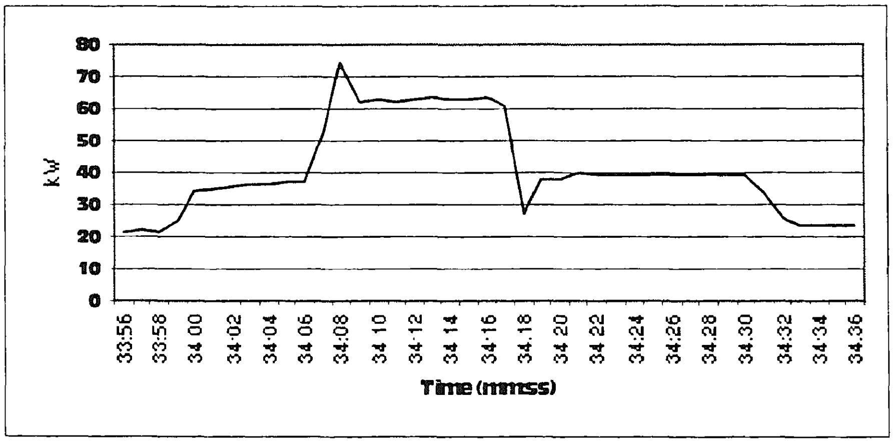


Figure 2b Variation of instantaneous power (RMGC - 2)

containers handled. It should also be noted here that the peak load on RMGC remains in the system only for few seconds.

2.1 Power factor

Since power factor also has a large bearing on the electricity cost as the plant is billed on kVAh consumption a study of instantaneous power factor was carried out for both the RMGC. Variation of instantaneous power factor for both the RMGC has been given in figure 2.1a and figure 2.1b. It is clear from the figure that power factor variation for RMGC-2 was in the range of 0.78 to 0.91. While the variation for RMGC-1 was from 0.38 to 0.92. The variation in the instantaneous power factor as seen from figure 2.1a and 2.1b is fairly rapid. The low power factor of RMGC would increase the kVah consumption therefore external compensation would be recommended particularly for RMGC-1.Since the variation of power factor with the load is fairly rapid mechanical switching of banks capacitor is not preferable. It is therefore recommended the static switching system be provided for switching on the installed banks. The plant should however consult the drive supplier for RMGC-1 before installing such a system.

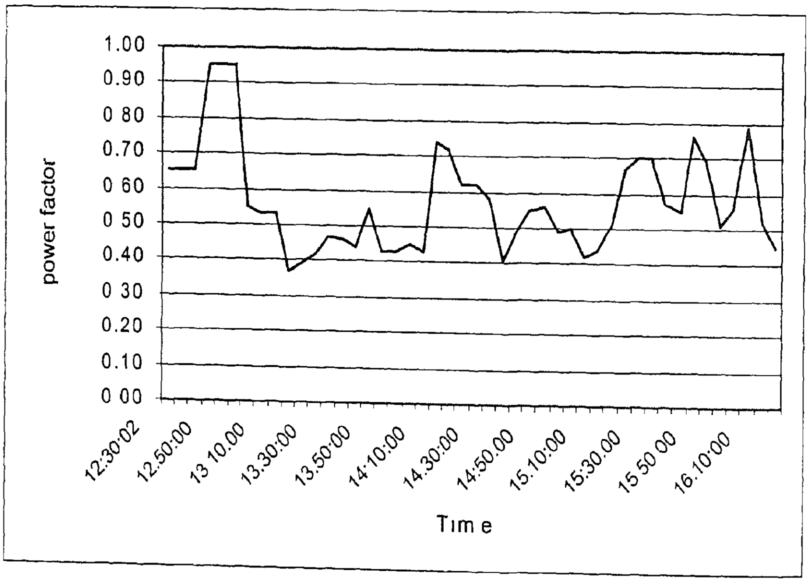


Figure 2.1a Power factor variation of RMGC-1

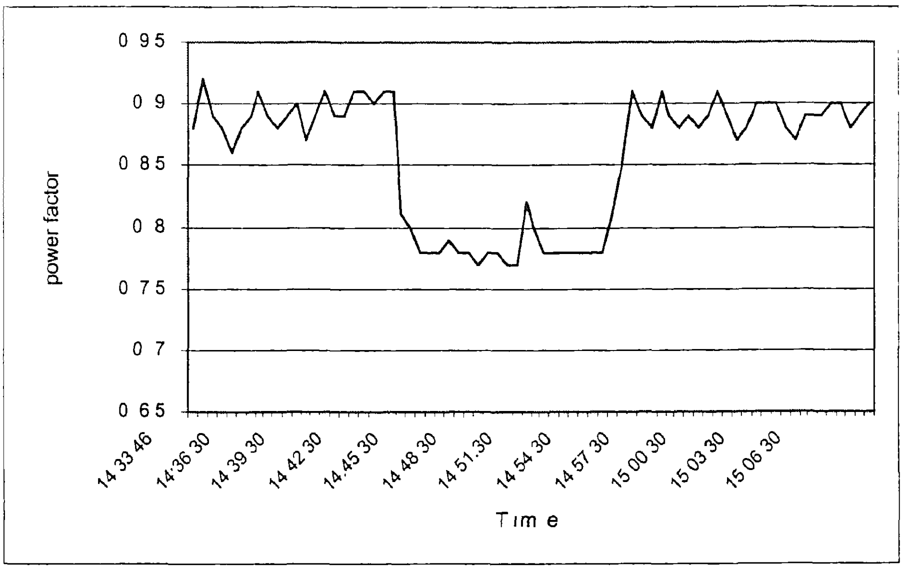


Figure 2.1b Power factor variation of RMGC-2

3 Transformers

CCI receives electric power from BSES at 11kV. The power supply at 11kV is further stepped down to 433V through 8 distribution transformers and is supplied to different load centres in the plant. The details of all the transformers installed in the plant is given in Table3.0.

Table 3.0 Rated Parameters of installed transformers

Transformer	Rated kVA	Voltage ratio
Work shop	400	11kV/433V
ADM TR-2	630	11kV/433V
ADB TR-1	630	11kV/433V
Refer	630	11kV/433V
TR-light	400	11kV/433V
Ware house	400	11kV/433V
RMG-1	630	11kV/3.3 kV
RMG-2	630	11kV/3.3 kV

.1 Transformer efficiency

Energy efficiency of a transformer is given by the following equation

$$\eta = \frac{\text{kVA} \times \text{powerfactor}}{\text{kVA} \times \text{powerfactor} + \text{Loadlosses} + \text{Noloadlosses}}$$

The maximum efficiency of a transformer occurs at an operating load when iron loss equals copper loss. The maximum efficiency point of the transformer is given by

$$\text{kVA(rated)}\sqrt{\frac{\text{Ironlosses}}{\text{Full load copper losses}}}$$

Operating an individual transformer at the point of maximum efficiency will result in lowest cost for energy losses of the individual transformer. It is therefore advisable to operate the transformer near the point of maximum efficiency. This is achieved in practice by optimising load on individual transformer.

Therefore energy audit of transformers were carried out to identify the present operating point with respect to the point of maximum efficiency based on Transformer Test certificates, current and voltage measurements and suggest ways decrease the losses and hence improve the existing operating efficiencies.

3.2 Design Losses

The designed losses of those transformers which are taken up for analysis are given in table 3.2. Table 3.2 also shows the load for which the transformers would operate at their designed maximum efficiency. These loading have been calculated from the test certificate of transformers.

Table 3.2 Design losses and efficiency of distribution transformers

Transformer	Rated kVA	voltage ratio(kV)	Full load loss (kW)	No load loss (kW)	Load for maximum effy (kVA)
Work shop	400	11/0.433	6.6	0.83	141.8
ADM TR-2	630	11/0.433	9.2	1.2	227.5
ADB TR-1	630	11/0.433	9.2	1.2	227.5
Refer	630	11/0.433	9.2	1.2	227.5
TR-light	400	11/0.433	6.6	0.83	141.8
Ware house	400	11/0.433	6.6	0.83	141.8

3.3 Transformer Loading

Transformer Data on current reading of distribution transformers (data for which were available) was collected. The load and the present operating point of individual transformers are given in table 3.3.

Table 3.3 Present operating point of individual transformers

Transformer	Rated kVA	Operating kVA	Loading	Calculated loss for max effy	Operating effy	max effy
Work shop	400	49	12.3%	35.5%	98.15%	99.35%
ADM TR-2	630	92	14.6%	36.1%	98.57%	99.42%
ADB TR-1	630	142	22.5%	36.1%	99.07%	99.42%
Refer	630	32	5.2%	36.1%	96.00%	99.42%
TR-light	400	17	4.4%	35.5%	94.85%	99.35%
Ware house	400	36	9.0%	35.5%	97.50%	99.35%

It is clear from table that operating point of all transformers are less then the point of maximum efficiency. Possibility of load optimisation was examined by discussion with plant personnel.. However it was possible in two transformers namely lighting and refer installed in the main substation.

3.4 Improvement options

It was observed that at present two transformers namely refer transformer and lighting transformers situated in close proximity to each other has a possibility to optimise loading in the system. Moreover there was substantial variation in the load of the two transformers. It is therefore recommended that both of these transformers should be coupled together by a common bus with a bus coupling arrangement. This arrangement would help in optimising the load as well as given the system additional flexibility in operation also leading to an increase in reliability. The proposed arrangement is given in figure 3.4.

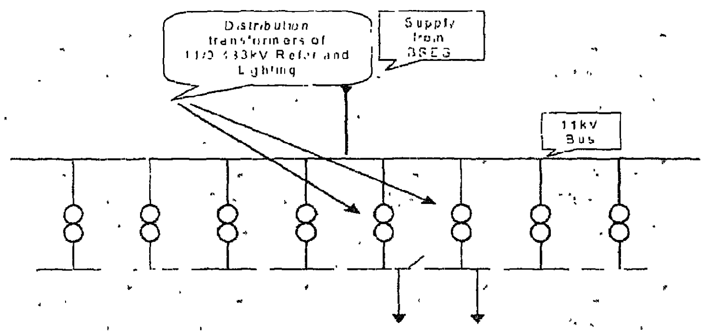


Figure 3.4 Installation of Bus couplers for flexibility in transformers

4 Demand management and power factor

4.1 Electricity distribution

Container Corporation of India receives power supply from BSES at 11 kV. The power supply at 11 kV is stepped down to 433V through eight distribution transformers and fed to different load centres in the plant.

4.2 Tariff structure

The plant has a contract demand of 2136 kVA, for which it is charged @ Rs 150 per kVA. Power billing is based on kVAh consumption during billing period with a unit electricity rate of Rs 3.90. Studies were carried out to optimise the existing contract demand.

Log sheets of the plant was analysed to identify the registered peak demand. Details of such a record for 10 July 2003 is given in Figure 4.2a. It was observed that the peak demand never exceeded 1600kVA. Even the peak load on the system contributed by the RMGs remains on the system only for few seconds and does not really contributed to registered peak system demand recorded by BSES. Therefore, the plant can retain additional 400 kVA as safety margin and reduce the contract demand to 2000 kVA by surrendering excess demand of

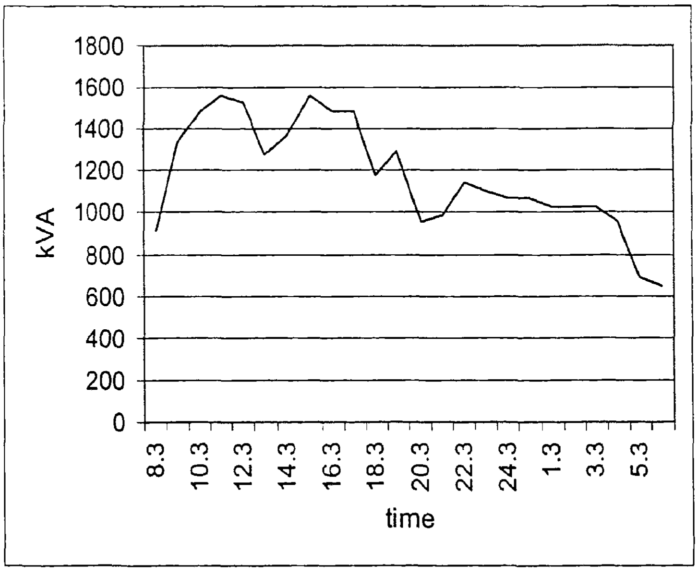


Figure 4.2a Load curve for a peak load period

136kVA. This measure would lead to a monetary savings of Rs 2,44,800/- (Rs 150 * 136kVA * 12months) annually.

In the view of reduction of the contract demand, measurement of the peak load of the plant was carried out once again on 23rd May Friday with TERI analysers with both the RMGs under operation. The results of the peak load measurement is given in figure 4.2b. It can be observed from the figure that peak load of Concor during measurements was found to be 1114kVA (with a power factor of 0.91). Peak load was also recorded from the Log sheets maintained in the plant as well as the maximum demand meter installed show that maximum demand during the month of April and May 03 never exceeded more then 1362kVA. Moreover as per BSES, the period for recording maximum demand is half hour. Therefore based on the above facts the plant can optimise the contract demand.

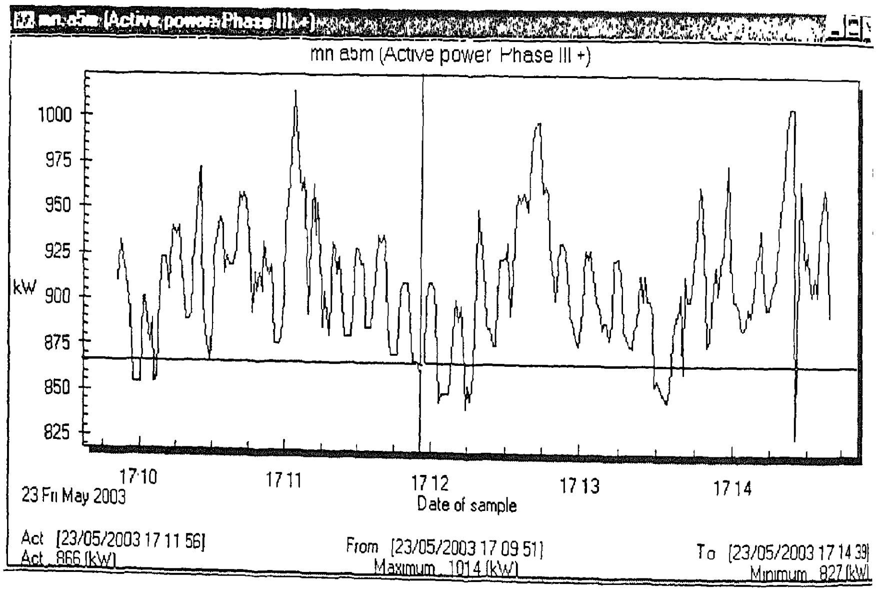


Figure 4.2b Peak load measurement

4.3 Energy accounting system

Energy accounting system of the plant was studied and details of existing meters and their locations are given in table 4.3a. Based on the discussion with the plant personnel, function requirement and energy intensity of the following metering scheme has been proposed (table 4.3b). The existing meter scheme will allow the plant to track changes in energy consumption at individual substation, major functional areas and high energy intensity loads.

Table 4.3a Meters installed in the plant

Transformers	Meters provided	Submeters provided
RMG-1	YES	
RMG-2	YES	
Lighting TR	YES	
Adm TR-(Old)	YES	Canteen
Workshop	YES	
Ware house	YES	
Refer TR	NO	
Adm TR-(New)	NO	

Table 4.3b Meters proposed

	Meters	Submeters to be provided
RMG-1		
RMG-2		
Lighting TR		TR complex feeder, compressors, private parties
Adm TR-(Old)		Custom feeders, CISF office, private parties, CISF office
Workshop		Workshop, colony, pumphouse, CISF base, private parties
Ware house		Custom feeders, import ware house, export warehouse, private parties, bonded warehouse
Refer TR	YES	Compressors, individual refers, private parties
Adm TR- (New)	YES	Custom feeders, private parties

.4 Power factor

The line current drawn by Induction motors, transformers and other inductive devices consists of two components; the magnetising current and the power producing current. The magnetising current is required to produce the magnetic flux in the machine. This component of current creates a reactive power compensation which is measured in kilo-volt amperes reactive (kVAR). The power producing current is that current which reacts with the magnetic flux to produce the output torque of the machine. This component of current creates the load power requirements measured in kilowatts (kW). The magnetising current and magnetic flux are relatively constant at constant voltage. However the power producing current is proportional to the load torque requirements. The magnetising current is essential for transferring power through the core of the transformer or across the air gap of an induction motor. The magnetising current lags the voltage by 90 degree. The total current drawn by the machine is the vector sum of this reactive current and the power producing current. The power factor is defined as the cosine of the angle between total current and power producing current vectors.

Low power factor leads to poor system efficiency as the high reactive component associated with low power factor gives rise to additional losses through out the system. An improvement in the power factor leads to

- Reduction of load on transformer and distribution equipment
- Reduction of load losses in transformers, distribution cables and other equipment
- Resulting in a direct savings of kWh power consumption
- Stabilisation of the system voltage

4.4.1 Present power factor scenario

The plant is presently maintaining a monthly average power factor above 0.87. The average monthly power factor of the plant was noted down from the electricity bills starting from June 2002 to January 2003. Figure 4.4.1 shows the variation and trend of monthly power factor for the above period. It could be observed from the figure that monthly power factor of the plant varied from 0.87 to 0.92. As per the tariff structure applicable to CCI, it does not have any penalty or rebate for maintaining an average power factor. However, since the plant is billed on kVAh, maintaining a high power factor would result in reduction in the billing amount.

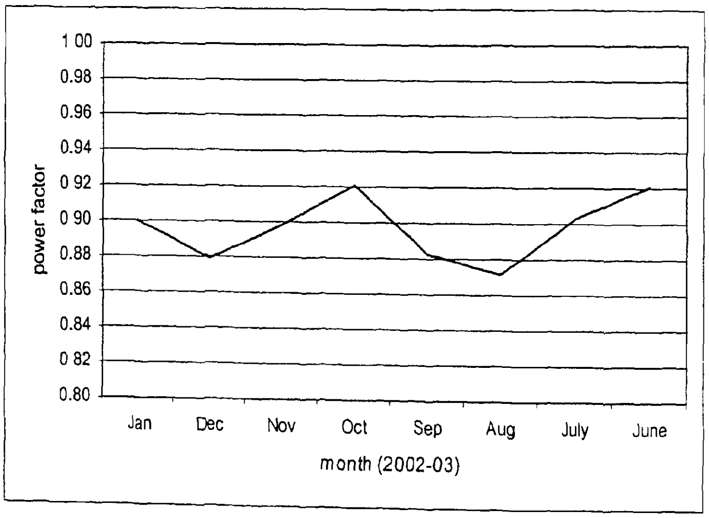


Figure 4.4.1 Variation of monthly power factor

4.4.2 Existing compensation scheme

A total of 770 kVAR of capacitor banks has been installed in the plant for improving the power factor. All capacitor banks are installed in the transformers and switched on through auto power factor correction relay. Details of installed banks with location are given in table 4.4.2.

Table 4.4.2 Details of capacitor banks installed

TR	Installed kVAR
ADM sub (old)	150
ADM sub	150
Work shop	100
Lighting	150
Refer	150
Warehouse	70
Total	770

4.4.3 Power factor measurements

Power factor measurements were carried out to evaluate the performance of the existing reactive power compensation scheme and suggest improvements.

4.4.3.1 Performance of the installed capacitor banks

The condition of all installed capacitor banks was checked to know the exact kVAR being supplied by these capacitors in the system. The measurements are presented in table 4.4.3.1.

Table 4.4.3.1 Performance of installed banks

Location	Average (AMPS)	KVAR	Capacity
ADM sub (old)	Not working		10
ADM sub (old)	13.9	10.0	20
ADM sub (old)	Not working		30
ADM sub (old)	19.3	13.9	40
ADM sub (old)	15.7	11.3	50
ADM sub	10.5	7.5	10
ADM sub	Not working		20
ADM sub	28.7	20.6	30
ADM sub	22.9	16.5	40
ADM sub	Not working		50
Work shop	17.7	12.7	10
Work shop	17.2	12.4	20
Work shop	Not working		30
Work shop	Not working		40
Lighting load	35.6	25.6	30
Lighting load	23.5	16.9	30
Lighting load	46.3	33.3	40
Lighting load	Contactor not working		50
Refer	10.1	7.3	10
Refer	Not working		20
Refer	30.3	21.8	30
Refer	39.0	28.0	40
Refer	45.7	32.8	50
Warehouse	11.8	8.5	10
	17.7	12.7	15

Location	Average (AMPS)	KVAR	Capacity
	23.6	17.0	20
	29.0	20.8	25
Total		329.5	770

It can be seen from the table that some of the banks were not working and some were supplying very less kVAR compared to its rated value. It is therefore recommended to replace these capacitor banks with new ones and also check all capacitor banks periodically and replace them whenever their value deteriorates to less then 50% of rated value. It can also be seen that at present 329.5 kVAR is being delivered to the system as against an installed capacity of 770 kVAR when all banks are switched on. The existing status was pointed out to the plant personnel and corrective action has been taken.

4.4.3.2 Power factor measurements at major feeders

Power factor measurements were carried out at different transformers to determine the operating power factor corresponding to the load, which was operating at the time of measurements and access the effectiveness of the compensation system in maintaining a high power factor (Table 4.4.3.2). It should be noted here that during measurements, capacitors banks were switch on through auto power factor correction relay.

Table 4.4.3.2 Power factor measurements on major transformers.

TR	Operating kW	PF
ADM sub (old)	126.59	0.89
ADM sub	89.93	0.96
Work shop	39.74	0.9
Lighting	10.98	0.62
Refer	31.14	0.95
Warehouse	36	0.98

It can be seen from the table that the compensation system installed in transformers namely admin (new), refer and warehouse has been found effective in maintaining a high power factor. While it was observed that for the banks installed in transformers adm and workshop was not able to maintain a high power factor. It is also seen that in lighting transformers the power factor measured was low.

4.4.3.3 Analysis of the existing compensation system

It is seen that on the whole, the plant has not been able to maintain an average power factor above 0.92 due to following reasons:

- Low delivering capacity of installed banks

- Improper switching of some of the installed banks
- Lack of external compensation at the RMGs

Therefore, it is recommended that for maintaining a higher power factor, the plant should take up the following measures:

1. Improve the delivering capacity of the installed banks to 1270 kVAR. The location of the banks that need to be installed to augment capacity of the installed banks to 1270 kVAR is given in table 4.4.3.3.
2. Tuning APFCR (auto power factor correction relay) for proper switching
3. Install 100 kVAR banks through static switching system at RMG-1 (Consultation with drive supplier).

Table 4.4.3.3 Location of proposed banks

TR	Installed kVAR	Additional Banks (kVAR	Additional kVAR
ADM sub (old)	150	100	250
ADM sub	150	100	250
Work shop	100	50	150
Lighting	150	50	200
Refer	150	100	250
Warehouse	70		70
RMG-1		100	100
Total	770	500	1270

4.5 Techno - economics of saving

Details of monetary savings due to improvement in the power factor that is calculated on the basis of last eight months electricity bills is given in table 4.5. Annual saving for three different average power factors has been calculated. It is clear that a maximum annual savings of about Rs 9.5, 13.5 and 17.4 lacs is possible by maintaining an average monthly power factor of 0.94, 0.96, and 0.98 respectively. The (tentative) investment for the proposed savings will be Rs 8.0 lacs.

Table 4.5 Techno-economics of savings

Month	KVAh	kWh	PF	kvah at 0.94 (1)	kvah at 0.96 (2)	kvah at 0.98 (3)	savings for 1(Rs)	savings for 2(Rs)	savings for 3(Rs)
2003 Jan	239520	215580	0.90	229340	224563	219980	39700	58334	76208
Dec	355500	312540	0.88	332489	325563	318918	89741	116756	142668
Nov	433380	389160	0.90	414000	405375	397102	75582	109220	141484
Oct	417900	384780	0.92	409340	400813	392633	33382	66641	98543
Sep	479460	423420	0.88	450447	441063	432061	113151	149750	184855
Aug	600420	523320	0.87	556723	545125	534000	170417	215651	259038
July	511440	461640	0.90	491106	480875	471061	79301	119204	157477
2002June	434400	399900	0.92	425426	416563	408061	35000	69566	102721
Total savings (Rs)							954414	1357683	1744491

5

Lighting systems

1 Introduction

Existing lighting systems at CONCOR TKD. can be divided in three groups mainly office or indoor lighting, warehouse lighting or industrial lighting and high mast tower lighting or floodlighting of areas. In office people not only spend time in reading and lighting but also on telephones and computers. Each of these tasks has its own visual requirement and lighting system is designed accordingly. In industrial lighting apart from visual requirement, safety and protection are equally important features of lighting design. High-mast lighting is preferred mainly on account of its economy in the use of lighting masts - a factor that contributes greatly to freedom of movement in the area illuminated.

The lighting system audit at CONCOR TKD. makes an attempt to establish how energy flows in lighting systems. It also reviews the existing lighting schemes for energy efficiency and energy wastage and finally recommends economically attractive energy conservation measures for lighting systems. All these are covered in following sections.

2 Lighting systems connected load

The connected lighting system loads at CONCOR TKD. is approximately 578 kW out of which 24 % is office or indoor load, warehouses load is around 23%, tower light accounts for 45% and remaining 7% are of workshop, water tank etc. lighting. The detailed lighting loads are given in annexure 5.1.

Lighting load is calculated based on following energy-input data.

1. Fluorescent lamps
   Lamp wattage : 40 W
   Energy loss in ballast : 12.5 W
   Total energy input in one fluorescent fixture : 52.5 W

2. High pressure sodium lamps (150 W lamp)
   Lamp wattage : 150 W
   Energy loss in ballast : 20 W
   Total energy input in one lamp fixture : 175 W

3. High pressure sodium lamps (250 W)
   Lamp wattage : 250 W
   Energy loss in ballast : 30 W
   Total energy input in one lamp fixture : 275 W

4. High pressure sodium lamps (400 W)
   Lamp wattage : 400 W
   Energy loss in ballast : 45 W
   Total energy input in one lamp fixture : 425 W

5. Metal Halide (400 W)
   Lamp wattage : 400 W
   Energy loss in ballast : 30W
   Total energy input in one lamp fixture : 430 W

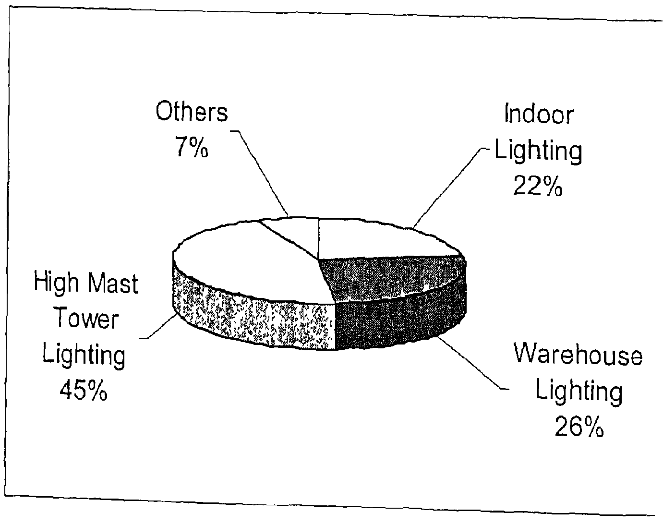


Figure 5.2 Lighting connected load

5.3 Estimated energy consumption in lighting system

Based on the operating hours of various lighting schemes the annual consumption has been worked out. The detailed calculation is shown in annexure 5.1. One major assumption which is taken in the estimation of lighting systems that the operating load is around 80% of the rated connected load.

As shown in figure 5.3, the total estimated annual consumption in lighting system is approximately 1917031 kWh or 2130035 kVAh. Indoor lighting accounts for 22%, warehouse lighting for 23% and high-mast tower lighting consumes 48% of the total energy consumption in lighting system.

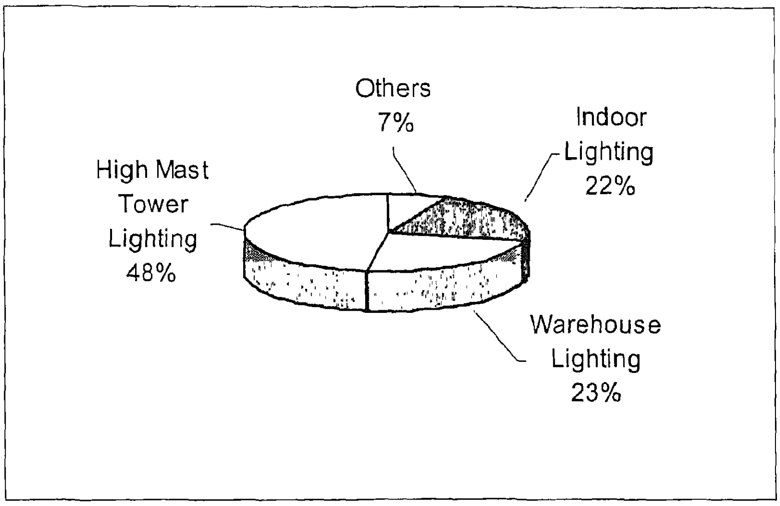


Figure 5.3 Energy consumption in Lighting System (Total consumption = 2130035 kVAh)

5.4 Review of existing lighting schemes at CONCOR TKD.

5.4.1 Data collection & field measurements

Significant savings in energy consumption, and therefore cost, of providing lighting without reducing standards can be achieved by incorporating energy efficiency approach to lighting installations. The objective is clearly to provide lighting to the quantity and quality standards required, with the minimum usage of electrical energy.

In order to assess how much existing lighting schemes are efficient or inefficient data have been collected and various measurements were carried out and they are listed below.

- Lamp-wise details of each room in CONCOR block of Admin building.
- Measurement of lighting levels in each room of CONCOR block of Admin building.
- Checking of control mechanism in each room of CONCOR block of Admin building
- Lamp-wise details of each room in CUSTOM block of Admin building.
- Measurement of lighting levels in each room of CUSTOM block of Admin building.
- Checking of control mechanism in each room of CUSTOM block of Admin building
- Lamp details of technical workshop
- Measurement of lighting levels in workshop both during day and night
- Control mechanism of workshop lighting
- Lamp details of technical offices
- Measurement of lighting levels in technical offices
- Control mechanism in technical offices
- Lamp details in export warehouse
- Lighting levels during day and night in export warehouse
- Control mechanism in export warehouse
- Lamp details in import warehouse
- Lighting levels during day and night in import warehouse
- Control mechanism in import warehouse
- Lamp details in bonded warehouse
- Lighting levels during day and night in bonded warehouse
- Control mechanism in bonded warehouse
- Lamp details of twenty one high mast tower lights
- Lighting levels in yards during night time
- Control mechanism of each high mast tower light

5.4.2 Observations

5.4.2.1 Indoor Lighting

- Monophosphor fluorescent lamps are predominantly used in offices, corridors of admin building, and in other indoor lighting except warehouses and workshop. This lamp consists of a long glass tube internally coated with phosphor and a tungsten filament at each end with an electron emissive material (i.e. barium and strontium) which emits electrons when heated. The electrons are drawn from one end of the tube to other through gas with mercury vapour. This reaction produces ultraviolet radiation, which simulates the fluorescent coating on the inside of the glass tube to produce light. A typical 40 W fluorescent lamp produces 2500 lumens.

- Ordinary type electromagnetic ballast is used in all fluorescent fixtures. A ballast is required to start and operate fluorescent lamps. They are manufactured with copper wire wound around steel laminate, similar to a transformer. The power loss in this ballast is about 12.5 W.
- 12% of the fluorescent lamps were found faulty.
- Wall mounted batten type luminaires along with surface mounted mirror optics batwing reflector luminaires are used as light fixtures for fluorescent lighting. A luminaire is a complete light fixture. It consists of a housing socket, the lamp and the components, which distribute the light. They provide safety to lamps and also direct and distribute light to desired area. Reflector luminaires are more efficient and they are used in approximately 76% of the installed fixtures.
- Measured lighting levels were less than the recommended lighting levels. The amount of light needed for a certain environment depends on the activity conducted in the area. The lighting level should conform to the recommended level of Bureau of Indian Standards Specification on Illumination. Inadequate lighting levels can decrease productivity due to visual fatigue created by poor lighting and can lead to an increase in level of work related injuries.
- All the lighting are controlled with manually operated switches. Master switches are not provided to switch off all lights of a room or area.
- "Switch off lights when you leave room" practice has not been followed by many. It was found during field survey that in many offices (some of them are having even more than eight fluorescent lamps) lights were kept on even though no body was inside the office. This leads to wasteful use of lighting system.
- Daylight is not been used in many offices for lighting. A lot of offices are having windows but these windows are either covered with dark curtain or glass painted dark to cut down the natural light. Electric lights were continuously used in these areas. Judicious use of natural light will enable

occupants to use less or no electric light in daytime leading to save precious electric energy.

5.4.2.2 High-mast tower lighting & Warehouse lighting

- High Pressure Sodium Vapour Lamps are predominantly used for warehouse & high-mast tower lighting. High pressure are the second most efficient (only low-pressure sodium is more efficient) lamps. Their small size and excellent efficiency make them most popular size for interior industrial applications such as in warehouses and also for area lighting. They are available in 70 W, 150 W, 250 W and 400 W size. Their other characteristics are given in table 5.4.2.2a.
- Apart from high-pressure sodium metal halide lamps of 400 W are also used for outdoor lighting near export warehouse. Metal halide lamps are less efficient than high pressure sodium but their colour rendering index (CRI) which measures the ability of light to show the true colour of an object in that light is better and preferred where better quality of light is required for executing visual tasks.
- Approximately 39% lamps were found faulty in High-mast tower lighting.
- 21% lamps of the total lamps installed to illuminate inside of warehouses were not operating
- Roof lights on warehouses and boundary wall lights particularly in Tehkand area and cement corporation area were not operating
- Reflector luminaires are used in all HMT lighting.
- Electromagnetic ballast is used in all outdoor fixtures.
- Measured lighting levels were not quite adequate. Area-wise lighting levels are given in table 5.4.2.2b.
- Lighting just after the Gate no-1 was very poor in night (less than 5 lux). This needs to be augmented since truck movement is very heavy during peak hours.
- There was hardly any illumination between empty stacks, between empty stack and stack-3, between stack-3 and stack-2, and stack-2 and stack-1. This is a very serious issue and must be resolved by appropriate lighting design of this area.
- Daylight utilization in bonded warehouse is excellent through skylights and hardly any electric lights are used during daytime. However, the situation is not as good in export and import warehouses. Additional use of electric lights is needed in these warehouses during daytime.

- Timers are installed on HMT lighting. They switch on the lights between 5:45 PM to 7 PM and switch off the lights from 5:00 AM to 6:30 PM. However it was found that most of the tower lights were on at 5:30 PM on a summer day. During field visit it was also found that four timers were not operating and there was slippage of 5 to 10 minutes in set times.
- Manual switches are provided near gate to operate group of luminaires in warehouses

Table 5.4.2.2a Lamps characteristics

S No.	Lamp type	Lumen output	CCT "K"*	CRI **
1	40 W-TL	2500	6500	68
2	36 W-TL'D	2450	6500	68
3	36 W-Trulite	3250	2700-6500	80-85
4	28W-T-5	2800-2900	2700-6500	80-85
5	150 W-HPSV	13500-14000	1900	20
6	250 W-HPSV	25000-27000	1950	25
7	400 W-HPSV	47000-47500	2050	20
8	250 W-MH	19000	4300	69
9	400 W-MH	35000	4300	69

* CCT, correlated colour temperature defines the colour of the light lower values show yellow light and higher values white colour of light.

** CRI, colour-rendering index defines the quality of light to show the true colour of an object in that light. The natural light has the best CRI and it is 100.

Table 5.4.2.2b Measured and recommended lighting levels

S No.	Area	Recommended (lux)	Measured (lux)
1	Offices	300	40 to 210 but majority of offices have illumination levels in the range of 80 to 160
2	Corridors	70	40-70
3	Toilets	50	20-40
4	Warehouse	50	Bonded warehouse Daytime : 90 to 220 Night time : 20 to 40 Export warehouse Daytime . 20 to 30 Night time : 30 to 50 Import warehouse Daytime : 20 to 30 Night time : 20 to 40
5	Storage areas with occasional traffic	5	10
6	Container terminals with frequent traffic	20	5 to 15
7	Fork lift trucks	10	10 to 20
8	Empty stack s and stacks3,2,1	20	Negligible
9	Road lighting in container terminals/marshalling yards	20	5 to 10

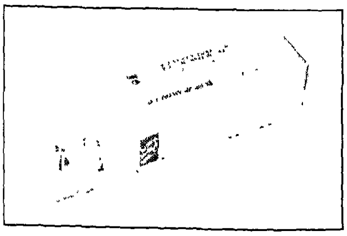
5.5 Energy conservation measures

5.5.1 No cost measures (Housekeeping Measures)

- Replace faulty (about 12% of total) fluorescent lamps in admin building since when lamp gets fused ballast remains in the circuit and power loss of at least 12.5 W continues for nothing.
- Keep daytime corridors lights off since this is a wasteful practice.
- Clean lighting fixtures in admin block mainly used in corridors and stairs. Dirty fixtures cut valuable light and some times in order to increase light additional fixtures are installed which increases the energy consumption.
- Switch off lights when room is not occupied. Keeping lights on when it is not required adds to energy wastage and cost. For example in CONCOR block office where lighting load is approximately 39 kW. Even in 50% of the offices if light is kept off for just 1 hour, this will save approximately 5850 kWh or Rs 26000 in a year.
- Use natural light in daytime either by using light coloured curtains or tinted glass.
- Replace all the faulty lamps in high-mast tower lighting it would save 44939 kVAh or Rs 199240 annually.
- Replace all the faulty lamps in warehouse since it leads to the wastage of 9986 kVAh or Rs 44270 per year.

5.5.2 Low & medium cost measures

Option-1: Replace electromagnetic ballast with super low loss ballast in fluorescent fixtures

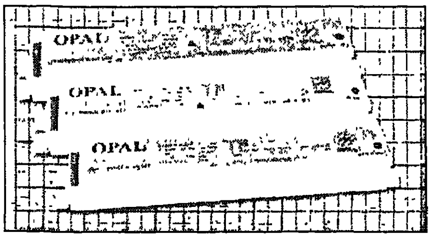


As mentioned above in normal electromagnetic ballast or copper choke the power loss is around 12.5 Watt. A single TL assembly fitted with 40 W lamp and copper choke operates at 52.5 W. In super low loss ballast the power loss is 4.5 W and there exists a potential to save approximately 8 Watts in each tube light fixture with super low loss ballast. It is therefore recommended to replace electromagnetic ballast in each fluorescent fixture. The anticipated benefits of this replacement are given below.

Total no. of fluorescent lamps : 2642
Total reduction in lighting load : 21.1 kW or 23.5 kVA
Total saving in energy quantity : 70435 kVAh
Total saving in energy cost (@Rs 3.99/kVAh) : Rs 281035
Initial investment required (@ Rs 300/choke) : Rs 792600
Simple payback : 2.8 years

Options-2: Replace copper chokes with electronic chokes in fluorescent fixtures

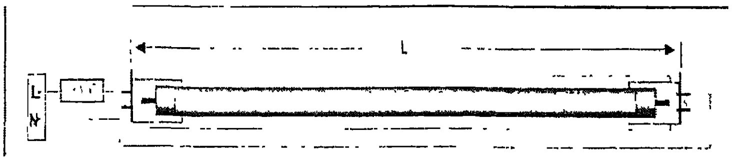
In electronic choke the power loss is almost negligible (1 to3) and there exists a potential to save approximately to save approximately 9.5 Watt in each tube light fixture with electronic choke as compared to electromagnetic ballast.

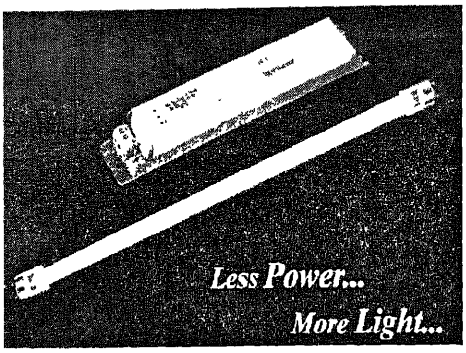


Total no. of single fluorescent lamps : 756
Total no. of twin fluorescent lamps : 943
Total reduction in lighting load : 25.1 kW or 27.9 kVA
Total saving in energy quantity : 83641 kVAh
Total saving in energy cost (@Rs 3.99/kVAh) : Rs 333730
Initial investment required : Rs 962500
(@ Rs 400/single fixture, @ Rs 700/double fixture)
Simple payback : 2.9 years

Option-3: Replace all the existing 40 W TL with energy efficient T-5 fluorescent tubes

Majority of the existing installation in CONCOR building is with T-12 (40 W) fluorescent lamps with electromagnetic choke (with average watt loss of 12.5 watts). The existing fluorescent tubes can be easily replaced by T-5 retrofit system consisting of 28W lamp with electronic ballast with less than 2W loss i.e. a total of 29 watts resulting in a saving of 23.5 watts per single fixture.

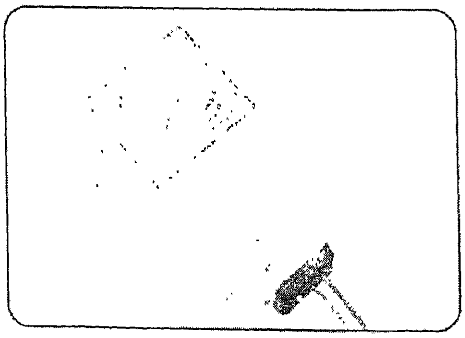


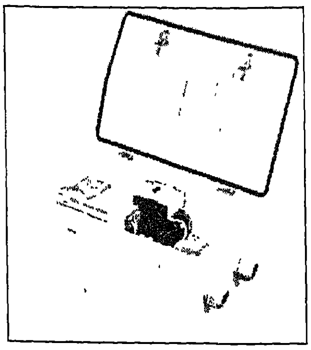


Total no. of fluorescent lamps	:	2642
Total reduction in lighting load	:	62.1 kW or 69.0 kVA
Total saving in energy quantity	:	206902 kVAh
Total saving in energy cost (@Rs 3.99/kVAh)	:	Rs 825540
Initial investment required (@ Rs 900/lamp)	:	Rs 2245700
Simple payback	:	2.7 years

Option-4: Replace existing timers in High-mast tower lighting with infra red operated switches

Normal timers switch on/off lights based on pre-set timings. If not corrected they do not correspond to the seasonal variation of daylight. It has been observed at CONCOR too that their timings are kept same irrespective of summer and winter. The timings are so set that the tower lights get switched on/off within 30 minutes. Hence tower lights remain switched on even when they are not required. This lead to substantial wastage of energy since the total load of tower lights is approximately 261 kW. Now infrared operated switches are available in the market, which can avoid such wastage in outdoor lighting. This switch has sensor which when senses infrared equivalent to less than 60 outdoor illuminance for more than 30 seconds switches on the light and when senses infrared equivalent to more than 10 lux for more than 30 seconds switches off all the lights.





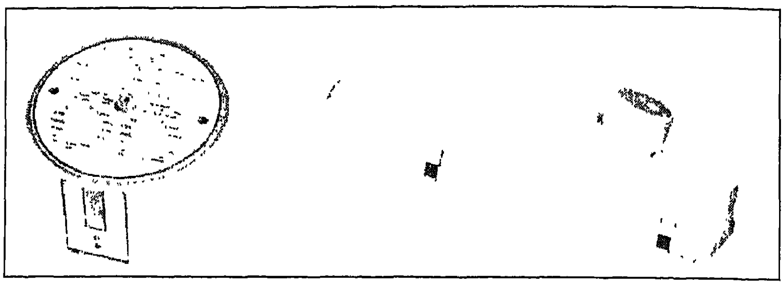
It is recommended to install one switch on each tower light to control all the fixtures installed in that particular tower light.

Number of towers	:	21
Number of switches to be installed	:	21
Total installed load	:	261.66 kW
Daylight saving (based on field monitoring)	:	1 hr/day
Total saving in energy quantity	:	106118 kVAh
Total saving in energy cost (@Rs 3.99/kVAh)	:	Rs 423410
Initial investment required (@ Rs 15000/tower)	:	Rs 315000
Simple payback	:	9 months

Option-5: Install energy saving device on High-mast tower lighting luminaires which enables them to operate at less wattage after some time and also acts as a infrared operated switch

In night when activities in the yards slow down it is possible to manage the things at slightly lesser illuminance. This enables the lamps to operate at less wattage than what they are rated for. Trend-setter which has all the quality of a infrared operated switch first switches on the light sensing the outdoor illuminance then reduces the wattage of the lamp after some set timing. At high-mast tower lighting which has twin 400-W HPSV lamps with 45 W ballast loss in each lamp it is possible to operate this fixture at 250 W with 25 ballast loss. It is therefore recommended that install one trend setter on each fixture to control one 400-W lamp. In a fixture one 400-W lamp will continue to operate at 400-W throughout the night but another can be reduced to 250-W for half of the night operating hours (6 hours/day). The saving potentials for such an operating is given below.

Fixture type	:	2*400 W HPSV
Total n. of HVSP lamps	:	588
Total no. of fixtures	:	294
No. of trend setters to be installed	:	294
Operating for first 6 hrs/night	:	261.66 kW
Operating load for next 6 hrs/night	:	211.68 kW
Total saving in energy quantity	:	197689
Total saving in energy cost (@Rs 3.99/kVAh)	:	Rs 788780
Initial investment required	:	Rs 654150
Simple payback	:	10 months

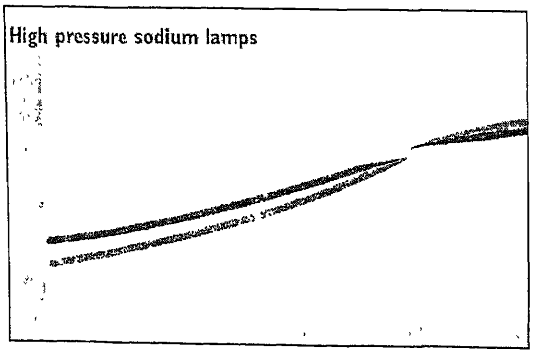


Option-6: Install luminous flux controller (Stabilux) on different sub-station panels to control light output of tower lights & warehouse lighting

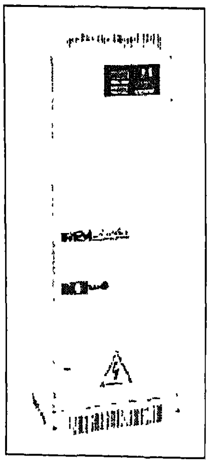
Stabilux Luminous Flux Regulator, which is a servomotor controlled auto-transformer and fully programmable automatic device to control lamp output by controlling its voltage. It utilizes a proven technology and saves 30 - 50 per cent power in discharge lamp installations. It also enhances lamp life by ≈ 100% and has got a very long equipment life, MTBF >200000 hours (>25years on 24 hour operation).

It also saves on lamp replacement costs by enhanced lamp life, supplies correct ignition voltage at all times, even after a grid failure and thereafter supplies stabilized voltage always. Saves an additional 5-7% energy by clipping nighttime high voltage. It is being manufactured by IREM Italy and got to be imported for use.

Stabilux can be installed at the panel, which supplies power to high-mast tower light and warehouse lighting. During low traffic conditions which occurs in night for six hours supply voltage can be programmed to get reduced to 90% of the rated which corresponds to 75% of the operating wattage as shown below. This will save substantial amount of energy and given below.



Green : Lamp wattage
Red : Illuminace
X axis : Voltage %



(A) Warehouse sub-station tower lighting

Total load : 106 kVA
Possible load reduction : 25%
Duration per night : 8 hours
Total saving in energy quantity : 77380 kVAh
Total saving in energy cost (@Rs 3.99/kVAh) : Rs 308740
Initial investment required : Rs 1500000
Simple payback : 4.86 years

(B) Main sub-station & RMG sub-station tower lighting

Total load : 97 kVA
Possible load reduction : 25%
Duration per night : 8 hours
Total saving in energy quantity : 70810 kVAh
Total saving in energy cost (@Rs 3.99/kVAh) : Rs 282530
Initial investment required : Rs 1100000
Simple payback : 3.89 years

(C) Admin sub-station & workshop tower lighting

Total load : 104 kVA
Possible load reduction : 25%
Duration per night : 8 hours
Total saving in energy quantity : 75920kVAh
Total saving in energy cost (@Rs 3.99/kVAh) : Rs 302920
Initial investment required : Rs 1500000
Simple payback : 4.95 years

(D) Export/Import/Bonded warehouse lighting

Total load : 154 kVA
Possible load reduction : 25%
Duration per night : 8 hours
Total saving in energy quantity : 112420 kVAh
Total saving in energy cost (@Rs 3.99/kVAh) : Rs 448550
Initial investment required : Rs 1900000
Simple payback : 4.24 years

- It finally rests with the CONCOR to select options for implementation basec on the available resource however, we recommend following options for implementation in order to get the significant benefits with reasonable expenditure.

- Replace existing fluorescent lamps (Tube lights) with T-5 lamps
- Install trend setters on high-mast tower lights
- Install Stabilux to control warehouse lights.

6

Diesel Generating (Small, Large Moving and Medium Stationary) Sets

There are sixteen small, four large moving diesel generating (DG) sets and two medium stationary DG sets in the depot. Sixteen small size dedicated sets as power pack are used in pairs for the refrigerated (REEFER) containers on separate rakes during their railway transportation. Four large size mounted sets are used to provide power for four rubber tyred gantry cranes (RTGCs) for their movement in and around the yard separately. The individual power pack is periodically coupled, operated with the REEFER containers for travelling from yard to the ports and de-coupled after returning to the depot, whereas the large size set is continuously moving with the individual RTGC. Two medium size stationary DG sets have been installed primarily to substitute the grid power supply, which is erratic. The rated capacity of individual DG set in three groups is different and the sets in each group are identical. The rated capacity of the individual small, medium and large set is 140 kVA, 625 kVA and 920 kVA respectively. The average engine load in the groups of small, medium set is about 55.0 percent (without capacitors), 62.3 percent (with capacitors) in Power pack no. 8 & 80%, 61.1 % and 47.5 percent respectively. The engine load in RTGC mounted large sets is varying at rapid rate, wide range depending on the container weight during hoisting and trolleying operation. Therefore, the average load level estimation in large sets is not feasible. Self-generated electricity of in-built large DG sets is used to meet requirement during the moving condition of RTGC, associated components in the depot, whereas the electricity of small size sets to meet continuous requirement during the rake running (on railway track) condition inside and outside the depot. Electricity from BSES Rajdhani Power Ltd. is used to meet the regular depot's requirement. HSD is used as fuel in the small, medium and large DG sets.

The compression ignition (CI) type engine is equipped with the number of cylinders. Each cylinder in the sets is fitted with one fuel injector. In stationary DG sets the turbocharger is selected to suit the pressure, flow and temperature of air at local ambient condition. In mobile sets the turbine-compressor match is selected of a compromise with the local working environment of engine, adequate margins on surge, turbocharger speed to cover other long distance running conditions. Although the operation under changing ambient conditions/ temperature introduces additional complications for the manufacturer of a turbocharged engine, the turbocharging system does offer partial compensation for reducing air temperature at cold weather. Each generator (small/ large) set with moving system is commissioned with the base/ platform mounting over the wheel/ tyre for movement. Normally, the distant window for individual small set is left open to remove the heat rejection (about 3-5% of input energy is radiated) by circulating air through the set during the running condition of REEFER containers. The Cummins made diesel engines and accessories have been supplied by M/s OVN TRADING ENGINEERS PVT. LTD., New Delhi. The air temperature inside the moving power pack cabin with REEFER containers and local atmosphere is supposed to be similar to maintain the designed performance level of the turbocharger. Each DG set has the individual air intake pipes fitted with filter. During the period of energy audit, one 140 kVA set (No. 8 retrofitted) with conventional containers numbers 12 without capacitors & 14 with capacitors, one 920 kVA set with RTGC (No. 3) and two 625 kVA sets were under operation for few hours. The design details of the DG sets are given in table 6.0.

Table 6.0 Design details of the DG sets in three groups

Parameter	Group 1 of medium sets (each 625 KVA)	Group 2 of large sets (each 920 KVA)	Group 3 of small sets (each 140 KVA)
Make	Cummins	Cummins	Cummins/ KEL, Kirloskar
Rating	Continuous	Continuous	Continuous
Engine model	K1 2300G	NTA 855 G	NTA 495 G/ N.A
AC Generator			
Capacity (kVA)	625	920	140
Voltage (V)	11000	415	415
Speed (RPM)	1500	1500	1500
Power factor	0.8	0.8	0.8
Current (Amps)	875	1280	195

N.A – Not available

The average temperature of gases inside the exhaust pipes at full load as per the DG sets (small, medium & large) manufacturer's recommendation is 449°C, 566°C and 480°C respectively. Depot personnel reported that the designed HSD consumption of the individual small (140 kVA) set is 18 L/hr at full load.

5.1 Operating characteristics and practices of the DG sets

The operating characteristics of the small, medium and large DG sets have been studied with regard to loading, specific energy generation ratio (SEGR), lube oil consumption and drain practices. The operating practices of HSD filling have also been studied. The measurements of energy related parameters were taken and the observations made are presented below. The bare exhaust pipes skin temperature of small, medium and large sets was measured using non-contact type temperature indicator and it was found that the skin temperature is okay. The thermocouple could not be used for exhaust gases temperature measurement because of the non-availability of suitable hole in the chimney. Based on the observations and the outcome of the analysis, some practical measures are suggested to improve the efficiency, thereby lowering the operating costs of DG sets.

Exhaust pipes skin temperature in small sets
- with 12 REEFERS. without capacitors = 290-300°C
- with 14 REEFERS. with capacitors = 370-390°C

Exhaust pipes skin temperature in medium sets = 315-325°C
Exhaust pipes skin temperature in large sets = 405-415°C

The estimated average temperature of exhaust gases inside the pipes would be 10-15°C more than the bare pipes skin temperature. Fuel-air mixture in the engine will not be the same for all cylinders unless the injection mechanism is individually adjusted, using the exhaust gases temperature as guide. The optimisation of the high very temperature of exhaust gases from the sets and its effect would require the following parameter to be attended.

1. High temperature of exhaust gases needs proper adjustment of injection pumps;
2. Temperature of exhaust gases should be measured using immersion probe thermocouple.

Each power pack is equipped with a fuel tank located inside the enclosure/ cabin cover on the short/ long distance moving rake, whereas each large size set is side mounted with a fuel tank on RTGC for movement in the yard. Each medium size DG set is equipped with a fuel tank located inside the building housing the DG sets. Fuel tanks with large, small size sets are filled almost at the beginning of the containers moving (inside/ outside the depot) operation. Normally, the HSD consumption is estimated for total operation in the specified period of 1-2 days.

Fuel tanks with small set no. 8, medium sets are graduated to estimate the hourly basis HSD consumption. There is no flow meter fitted with these sets for the measurement of HSD. However, the HSD in a 2000 litres tank with flow meter mounted mobile workshop is used for filling tanks with all sets. The fuel tanks in the small, medium sets are placed at accessible location/height, fitted with indicator, graduated for HSD level indication whereas the tanks with large sets at a height of about 2.5 metres and without any level indicator. The HSD tank's capacity of the large generator set is 1000 litres and its filling pipe at the top surface. The individual large set is with the RTGC and the low level of HSD in tank is not allowed to reach, avoid engine's hunting. Everyday the individual large set with RTGC is taken 1 hour shutdown for cooling purpose. The regular level inside tank is very important for quick estimation of used/ balance HSD quantity, everyday filling practice between 10.30-11.30 hours, as filling above the reference point would crate fuel surplus for the RTGCs extended period (night time) operation because of containers varying load and filling below the point create fuel shortage. Thus, more the HSD level above the reference point more would be the residual HSD and wide filling interval. Similarly, less the containers in the yard less would be the HSD filling required for average consumption. Month-wise (August 2002 – January 2003) data such as number of moves, HSD filled quantity and operating hours of RTGC #3 was available from the logbook. The monthly average HSD consumption per move and per hour calculated for six months is given in the table 6.1.

Table 6.1 Month-wise moves number, HSD consumption & operating hours for RTGC #3

Month	No. of moves	HSD consumption (L)	Operating hours**	HSD consumption rate		
				(L/ move)	(L/ hr)	(L/ day)*
August 2002	7066	11860	598.88	1.7	19.8	455
September	7029	10498	614.16	1.5	17.1	393
October	6946	10721	618.68	1.5	17.3	399
November	5511	8936	500.86	1.6	17.8	410
December	6886	11707	618.36	1.7	18.9	435
January 2003	6070	11152	541.41	1.8	20.6	474
Total	39508	64874	3492.35			

* Net HSD consumption in 23 hours.

** After reported 5% operating hours subtraction

The monthly average moves number per day, HSD consumption for the set with RTGC #3 is calculated to be 260 moves/ day, 1.6 litres/ move and 428 litres/ day respectively. Depot personnel reported that the HSD filling, level observation inside tanks is manually done for last 2-3 years and the level regularly made up to the maximum height of the tanks. They also reported that there was a floatlevel indicator working simultaneously to control the HSD filling system. Presently, the indicator used for maintaining the HSD level is out of order. The HSD filled quantity and operating hours collected from the RTGC #3 logbook for the period March 1-20, 2003, as given in the Annexure 6.1. The average HSD consumption for the set is calculated to be 21.2 litres/ hr or 487 litres/ day. The HSD filling quantity, time in RTGC #3 is monitored to be 500 litre and 13 minutes on April 21, 2003. Presently, the HSD consumption per day is on the higher side. Thus, more the HSD consumption above average level proportionately more would be the containers handling possibility in the yard. The HSD consumption, filling profile should show the actual containers handled over a period by the individual RTGC is satisfactory and close to either the design or best average level.

The everyday conventional filling system of HSD tank in RTGCs is to improve with the latest type of level indicator installation. The monitoring of everyday level and used/ balance HSD should be done with the highest accuracy level. It is recommended to replace the present filling systems by the new high efficiency level transmitter/ level gauge. The benefits of using the new system with RTGCs will be the HSD level display at any point of time, no overflow and correct filling. The firm quotation for level transmitter/ level gauge system for HSD tank filling from the M/s V. AUTOMAT & INSTRUMENTS (P) LTD. is enclosed in the Annexure 6.2. The investment required for a new level transmitter/ level gauge system is between Rs. 29.5-35.5 lakhs.

6.2 Loading of DG sets

At Tughlakabad inland containers depot, one medium stationary DG set in operation and loading on the set varies from time to time, depending on the load and availability of grid power. During the first site visit between January-February 2003 and trial with two DG sets (625 kVA each), the load on the individual set could not be maximised. Normally, one 625 kVA set is loaded to the extent slightly higher than either 61 percent or 47 percent when there is no grid power available and the second medium DG sets is stand by. It implied that the full capacity of the DG sets is not utilised. Depot personnel asked for the second trial with maximum load on the individual DG set during one of the peak summer days. The DG-1 (625kVA) generally provides standby power to Administrative building (CONCOR), Warehouse, Workshop and residential colony. The DG-2 (625kVA) generally provides standby power to RMG-2, RMG-

1, Refers and Air compressors. During the night, the DG-2 takes lighting in yard in lieu of CONCOR in day.

During the second trial in May 2003, the field tests was carried out on DG set #2 with RMGC-1, RMGC-2, and 19 refers (Air compressors were not in operation during the field measurement. The load on the set #2 set was monitored (logged with a time interval of one second) by using online power analyser. The variation in the loading for the set #2 is given in figure 6.2a. It is clear from the figure that that peak load measured on the set #2 was 506 kVA (amps 26.6). Therefore the set #2 was loaded to about 80% of its capacity. It can also be observed from figure that there was a sudden shoot up in the load primarily because of the hoisting operation of individual RMGC. It is generally recommended that the DG set #2 has to be kept slightly under loaded to take on such jerking loads. However, it is observed by field measurements that the loading on DG set #2 is on the higher side considering the type of load. Moreover, the air compressors and full refer load was not in operation.

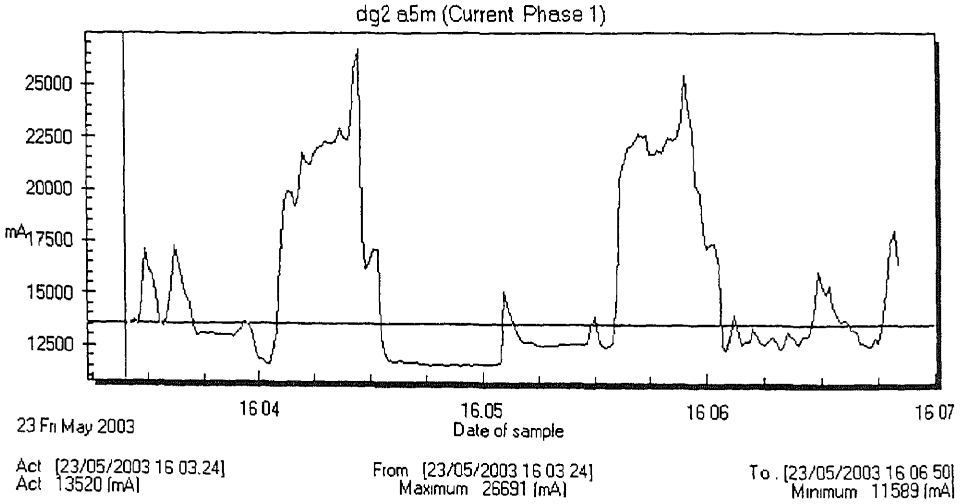


Figure 6.2a Variation in loading for the set #2

During the first trial between January-February 2003, the field test was carried out on DG set #1 and set #2. The actual engine load on the set #1, #2 was monitored to be 61.1% and 47.5% respectively. Table A6.3 in the Annexure 6.3 shows the load variation on the sets for almost 1 hour at 5 minutes interval basis. The load on two number DG sets was calculated based on the data collected on January 29, 2003, which is shown in chart for two sets. Figure 6.2b and figure 6.2c shows the 5-10 minutes basis engine load on the Set #1, Set #2 respectively.

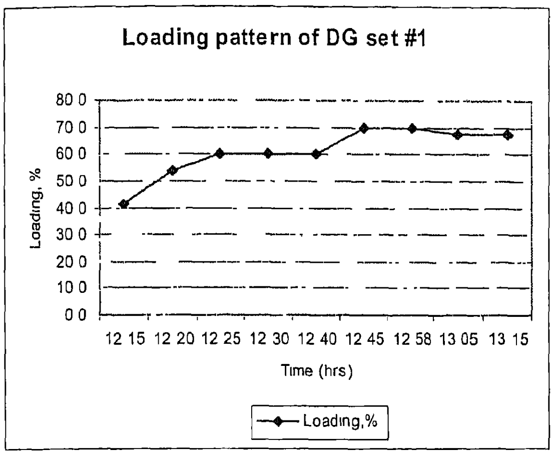


Figure 6.2b Variation in percentage loading of medium DG set #1

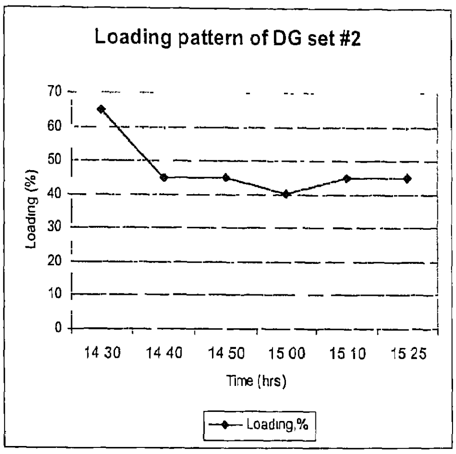


Figure 6.2c Variation in percentage loading of medium DG set #2

One rake of 12-14 REEFERs fitted with one power pack (two sets of 140 kVA capacity each) is operating (one set at a time) at moving/ stationary condition and loading on the set varies from time to time, depending on the local heat load/ ambient temperature and running speed. Normally, one 140 kVA set is loaded to the extent between 55.0-62.3% when the power pack is at stationary condition. However, it would vary slightly higher than either 60 percent or 65 percent when there is a variation in local ambient temperature accompanied by the significant change in speed. The actual load on the set #4 of power pack no. 8 without capacitors, with capacitors is monitored to be 55.0% and 62.3% respectively. Table in the Annexure 6.3 shows the load variation on one small set at stationary condition for almost 30 minutes at 5-10 minutes interval basis. The engine load on one number small DG set at two conditions has been calculated based on the data collected on April 3, 2003, which is shown in chart for one set.

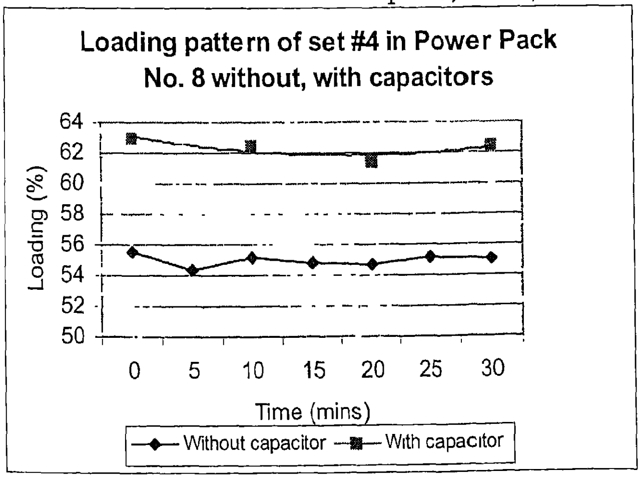


Figure 6.2d Variation in percentage loading of small set #4 with & without capacitors

Figure 6.2d shows the same duration basis load on the Set #4 without capacitors and with capacitors respectively.

SEGR of a DG set is a performance indicator, which is proportional to the extent of loading of the set. The standard variation of SEGR value with the loading of a set is shown graphically in figure 6.2e. It clearly demonstrates the above fact. At part load operation, the efficiency of the DG set drops down with a consequent decrease in the SEGR value. The specific energy generation ratio (SEGR in kWh/litre) for 140 kVA, 920 kVA and 625 kVA sets is computed from the designed specific fuel consumption (SFC in gms/ BHP per hour). The supplier reported that the SEGR at different loading of three type DG sets is almost similar and SFC of 140 kVA, 920 kVA is same. The designed SEGR of the 140 kVA, 920 kVA and 625 kVA sets at different loading is given in the table 6.2a.

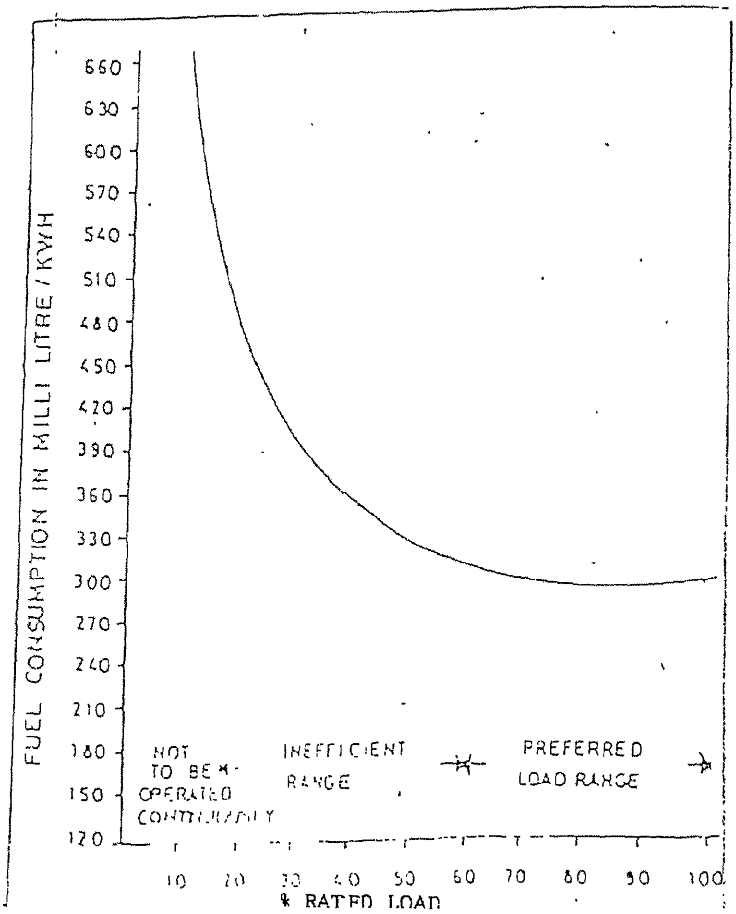


Figure 6.2e Standard variation of SEGR value with the loading of a DG set

Table 6.2a Design SFC & SEGR of 140 kVA, 920 kVA & 625 kVA set

Loading (%)	SFC(gms/ BHP per hour)	SEGR (kWh/L)
140 kVA & 920 kVA		
100	153.2	4.04
80	155.2	3.99
60	159.9	3.87
625 kVA		
100	150.0	4.13
80	152.0	4.07
60	156.6	3.95

The actual fuel consumption, kWhs generated and operating time of the Set #1, Set #2, Set #3 and Set #4 are measured. The level change in the fuel tank with set #1 and set #2 is measured using a capillary tube scale. The actual consumption of fuel with set #3 of power pack no. 8 without capacitors and with capacitors is measured using an HSD filled 40 litres can. The SEGR calculation is given in the table 6.2b.

Table 6.2b Operating data for DG sets

Sl. no.	KVA/No. of Set.	Monitoring time (mins)	Units Generation (kWh)	HSD consumption in 1 hr (l)	Units Generation in 1 hr (kWh)	SEGR (kWh/l)
1	625/ #1	60	400	101.5	60	3.94
2	625/ #2	55	240	88.1	262	2.97
3	920/	23	25	7.45*	65	3.34
4	140					
	-12 REEFERS	30	32	20.2	64	3.17
	-14 REEFERS**	30	30	21.24	60	2.82

* Consumption in 23 minutes, ** Load added with 2 extra REEFERs

As can be seen from above table, the operating SEGR value of the set #1 and #2 is slightly lower than the manufacturer's recommended (the design values) range for 50 - 100% loading. The SEGR of short duration operating set #4 at stationary condition and 55% (without capacitor) & 62.3% (with capacitor) engine loading is well below the recommended range. However, the specific fuel consumption (SFC) increases with the engine load from 0.315 l/kWh to 0.354 l/kWh. The SEGR would improve during continuous operation of longer duration.

Month-wise (January–December, 2002) data such as fuel consumption, kWhs generated and hours of operation of two medium DG sets was available from the logbook. The SEGR calculated for two sets is given in the table 6.2c. Figure 6.2f shows the month-wise SEGR of the Set #1 and Set #2 respectively.

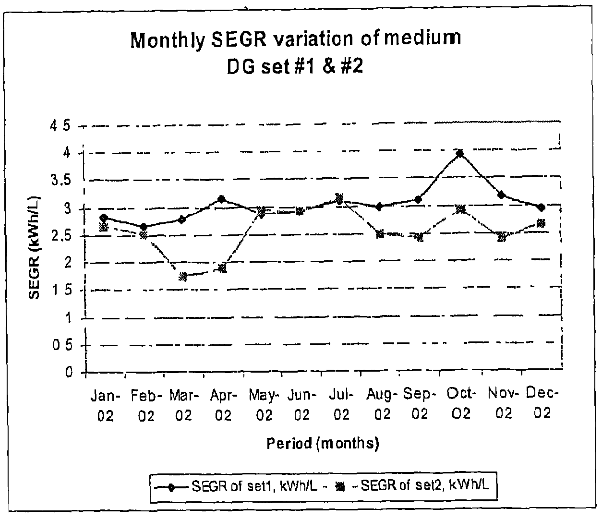


Figure 6.2f Monthly SEGR variation of DG set #1 & #2

The SEGR calculation for set #1, Set #2 based on monthly data is given in the Annexure 6.4 (table A6.4a, A6.4b). The average SEGR of the sets is calculated to be 3.04 kWh/l and 2.57 kWh/l respectively. It was found that the SEGR of the set#1, set #2 at respective load was lower than the manufacturer recommended level 3.95 kWh/l and 3.66 kWh/l respectively. The monthly kWh (electricity generation) data for SEGR calculation of set #3 and set #4 is not available. The actual SEGR of the individual set is to be periodically checked to maintain between the recommended level 3-4 kWh/l maximum by any manufacturer.

Table 6.2c Month-wise SEGR for set #1 and set #2

Month	SEGR (kWh/l) of medium set #1	SEGR (kWh/l) of medium set #2
January 02	2.82	2.67
February	2.67	2.53
March	2.78	1.75
April	3.16	1.89
May	2.88	2.94
June	2.92	2.93
July	3.1	3.15
August	2.99	2.5
September	3.11	2.42
October	3.94	2.93
November	3.17	2.41
December	2.95	2.67

N.A - Not available

The SEGR (kWh/l) of set #3 and #4 could not be computed. Month-wise operating hours have been collected for set #1, set #2 for the period January to December, 2002 and set #4 with power pack no. 8 for 3 months period. Based on 6-12 months average, the operation of the generator set #1, set #2, set #3 and set #4 is 19.4 hours/month, 21.4 hours/month, 612.7 hours/month and 27.2 hours/month respectively. Its profile should show the overall SEGR value of the individual generator set is satisfactory and close to the design level.

6.3 Lubricating oil usage

The recommended grade for lubricating oil by the DG sets (#1-#4) manufacturer (Cummins) is 15W 40. This is a multi-grade oil having a viscosity of 15W-40 only. The lubricating oil is supposed to be drained in the large, medium and small sets after every 300 hrs and 250 hrs of operation as per the manufacturers' latest recommendation. However, the lube oil is draining as it was being done earlier as per recommended interval for the large, medium and small sets either 250-300 hours or 6 months, whichever is lower. The manufacturers' recommended the drain interval at the time of installation of large and medium sets either 250 hours or 6 months, whichever is lower.

The initial lube oil charge to the sump in the set #1/#2, set #3, #4 is 160 L, 160 L and 24 L respectively. The recommended lube oil consumption in the sets within and beyond warranty period is 200 ml/hr and 50 ml/hr respectively. The lube oil consumption for the set #1, #2, #3 and #4 was estimated to be about 533 ml/hr, 533 ml/hr, 88 ml/hr and 96 ml/hr respectively. Any increase in the operating hours of the set #1 and #2 would proportionately decrease the lube oil consumption.

The recommended oil drain level can be extended further without damaging the engine by "condition-monitoring" of the used lubricating oil. There are certain physico-chemical properties of lube oil which must be evaluated to assess the condition of the used oil. These properties are: (i) viscosity at 40°C and 100°C, (ii) total base number, (iii) water content, (iv) insoluble build-up. It is recommended to monitor the lube oil condition on a regular basis using a portable test kit which will help in extending the drain interval thus saving on valuable lube oil. However, as regard the check parameters, test procedures and the corresponding rejection limits, the DG sets manufacturer has to be consulted. Facilities required to carry out these tests can be provided in-house and this costs around Rs. 35000. The cost of the monitoring system would be paid back from the savings due to longer engine oil actual drain periods resulting in reduced lube oil consumption.

The lube oil consumption must be monitored for individual DG set along with fuel consumption details. The ratio of lube oil to fuel consumption is indicative of mechanical efficiency of the engine. The ratio of the set #1, #2 and #4 is within the permissible (the recommended values) level. It is estimated for set #3 to be above 0.02. The manufacturer is to be reported for the high level of lube oil consumption and lube oil to fuel ratio in continuously operating DG sets. Generally, the recommended ratio of lube oil to fuel is 0.01.

6.4 Engine cooling system

The stationary engine, sets are cooled by water and engine of moving set by air.

6.5 Local suction air temperature around running rake, cabin cover for small DG sets in power pack

The small sized air intake pipe and the filter of the small generator sets are located within the cabin cover. The temperature of suction air to the DG set is very important as rise in temperature will increase the energy consumption for compression because of increased volume of air. Thus, less the temperature of air at the suction less would be the energy consumption for compression.

Ambient temperature and air temperature inside DG sets cabin cover at stationary condition is measured using temperature indicator and it is found that the temperature of the suction air to the sets above the ambient temperature. The temperature (inside cabin) air measured for two conditions of set #4 is given below. The turbocharged aftercooled engine can be operated without any loss in power up to 1500 metres elevation and 38°C ambient temperature as per the recommendation of any DG sets manufacturer's.

Ambient temperature = 32.3°C
Suction air temp. inside cabin of DG set at 55% load = 37°C
Suction air temp. inside cabin of DG set at 62.3% load = 38°C

The average air temperature (inlet, before filter) to the cabin of DG sets is high and it could be higher at travelling conditions. Significant air is to pass through the suction filter while the DG sets along with the door (at sides) close cabin are placed on the rake. However, care should be taken against any possible change in temperature and flow of suction air through openings to the generator sets.

6.6 Recommendations

Following measures are recommended for the performance improvement of the generator sets.

1. Irrespective of the number of DG sets in operation, it must be noted that the DG sets be loaded to the optimum level (80 percent). This will ensure the best operating condition of the DG sets.

2. Review the number of containers to be handled by RTGCs everyday and install the new level controller/ indicator system to avoid the filling of extra quantity of HSD in the tank. The reviewing and controlling system together should be capable to adequately utilise the fuel in operating RTGCs. The firm quotation of the new level controller/ indicator system is yet to be obtained from the suppliers.
3. Suction air to be maintained at the temperature close to ambient throughout the DG set operation in all seasons. Manufacturer should be contacted to predict the turbocharger and engine performance of set #4 with the wide change in the suction condition (temperature and flow) of air because of the closed type cabin cover installation.
4. It is recommended to consult manufacturer/ supplier for the revised SEGR (considering high load fluctuation, speed variation) of small 140 kVA and large 920 kVA sets. It is also to maintain the overall (latest) SEGR value for the individual generator set close to the recommended level by the manufacturer.
5. Temperature of the air supplied to the suction of DG sets should be monitored periodically to ensure that it is, at least, equal to the ambient temperature.
6. High temperature of exhaust pipe adjacent to engine in set #4 needs proper shielding the exhaust ducts with asbestos rope.
7. Ensure proper maintenance arrangements of windows other than nearby doors, its opening at the cabin on the running rake.

7

Pumps

Pumps consume about 2.9% of the total annual electricity consumption. Energy audit of pumps was carried out to determine the operating energy performance of pumps and identify measures for improving the same. The rated parameters of the pumps have been given in table 7.0.

Table 7.0 Rated parameters of the water pumps installed in CCI

Application	Rated Head (Metres)	Rated Capacity (M^3/hr)	Rated kW of the motor	RPM
Booster pump	34.5	84.6-34.2	7.5	2900
Submersible pump-1	45/80	22-14	7.5	2850
Submersible pump-2	NA	NA	5.5	NA

7.1 System descriptions

Ground water is pumped to underground tanks (3nos) of 50760 litre by two submersible pumps. The stored water is then lifted to overhead tanks of capacity 146167 litre. The water from over head tanks is supplied to various areas like administrative building, concor colony, yard, workshop, sulubh sauchalaya, etc. As per present operating practice, two submersible pumps are operated while generally one of the booster pumps are operated.

7.2 Energy audit of water pumps

The output power of the motor, which is assumed to be equal to the input power (sometimes called the brake horsepower) to the pump, is given by

$$P_{input} = \text{input power of the motor} \times \text{efficiency} \quad (1)$$

7.2.1 Output power

The output power (sometimes called the water horsepower) of the pump P_{out} is equal to the rate of work done on the fluid, namely

$$P_{out} = yQh_p' \quad (2)$$

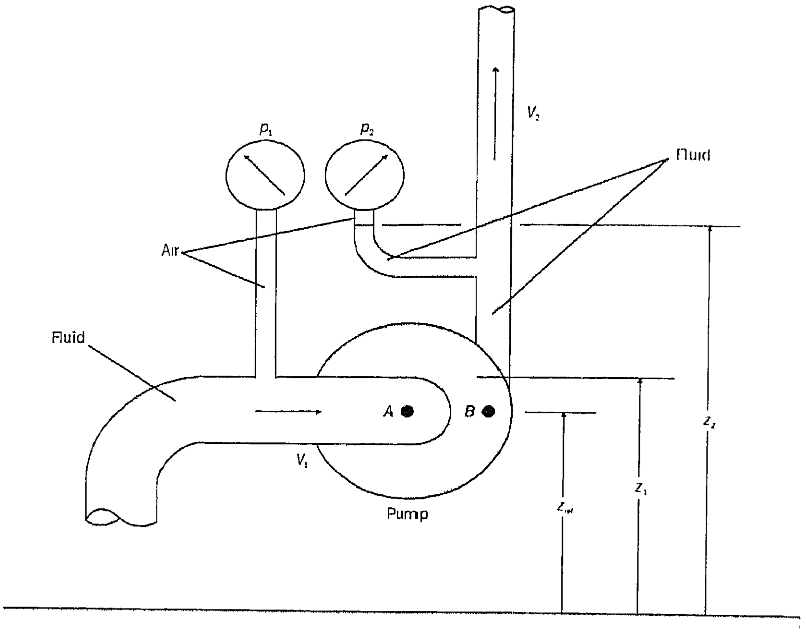


Figure 7.2.1 Interpretation of elevation z_1 and Z_2

Where y is the specific weight of the fluid, Q is the volumetric flow rate, and hp is the energy increase per unit weight, or pump head, supplied to the fluid between inlet A and out B of the pump (figure 7.2.1)

$$\left[\frac{p}{\gamma}+\frac{V^2}{2g}+z\right]_A + h_p = \left[\frac{p}{\gamma}+\frac{V^2}{2g}+z\right]_B \qquad - \quad (3)$$

Since A and B are at the same reference height z_{ref}, this expressions simplifies to

$$h_p = \frac{P_B - P_A}{\gamma} + \frac{V_2^2 - V_1^2}{2g} \qquad - \quad (4)$$

Where, in general, the entrance V1 and the exit velocity V2 have been assumed to have same values since the inlet and outlet pipe were almost same.

7.2.2 Pump efficiency

The efficiency of the pump is simply the ratio

$$= \quad P_{out}/P_{in}$$

which is usually expressed as percentage. This efficiency is found to be a function of the flow rate, and is therefore not just a constant for a given pump.

Efficiency is an important characteristic of a pump, since, as indicated in Figure 7.2.2, the difference $P_{in} - P_{out}$ represents power that is lost.

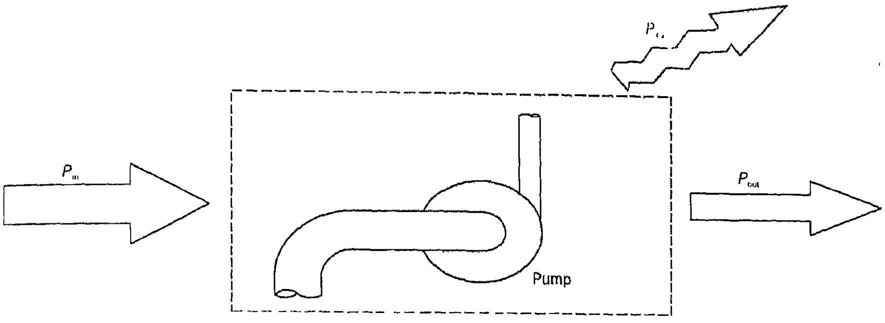


Figure 7.2.2 Schematic of input and output power

7.2.3 Pump characteristics

The manufacturers of pumps provide pump characteristics curves for their products. Fundamental variables appearing in pump characteristics curves are the input power P_{in} – P, flow rate Q, pump head h_p, output power Pout = Qh_p' and efficiency = P_{out}/P_{in}. Usually, flow rate Q is chosen as the independent variable, and the other quantities are plotted as functions of Q.

Manufacturers' curves are often quite compact, being simply plots of pump head h_p as functions of Q, with efficiency appearing as a parameter along each curve. Only one such curve is needed to characterize a given pump completely.

7.3 Computation of the efficiency of the pumps

The Flow rate of the pumps was measured with water flow meters. The discharge pressures were noted down from pressure gauges, input power to the motor was taken from the meters installed in the field/ measurements. The efficiency of the motor for calculation purposes was assumed to be 85%. Sample computation of pump efficiency for booster pumps is shown below.

Measured head = 30 m
Measured flow = 25 m^3/hr
Hyhraulic power = 2.04 kW
Motor input power = 6.8
Efficiency of the motor = 85%

Input (kW) to the pump = 5.78

Efficiency of the pump = 35 %

In the similar way efficiency of the other pumps has been computed, the results of the same is given in Table 7.3.

Table 7.3 Efficiency of pumps

Pump	Flow (m^3/hr)	Head (M)	Input power	Efficiency	BEP (%)
Booster pump-1	25	30	6.8	35%	57
Booster pump-2	30	33	8.4	38%	57
Submersible pump-1	11.8	70	4.7	56%	65*
Submersible pump-2	16.9	59	5.2	61%	65*

Discussed with supplier

7.4 Results and analysis (BEP)

The efficiency of the pumps was computed and the same has been compared with the design figures. It is recommended to operate the pump at flows as close to the BEP. Because the operating cost as well as the loads on the other rolling elements is minimum at this point. However due to a host of practical limitation like variation in throughput, excess capacity for future expansion etc it is not always possible to achieve the same. For the purpose of evaluation of pump energy performance comparison of operating efficiency with the BEP and design value is done to access the deviation in these parameters. All the pumps were operating at efficiencies less than BEP (Table 7.3).

7.5 Motor loading

The shaft loading of individual pump motor were also computed for all installed motors and result of the same has been given in table7.5.

Table7.5 motor loading

Pump motors	Rated (kW)	Voltage	Operating kW	PF	A	Loading (%)
Submersible pump-2	5.5	402	5.2	0.77	9.81	81
Submersible pump-1	7.5	398	4.7	0.72	9.35	58
Booster-1	7.5	425	6.8	0.7	13	81
Booster-2	7.5	421	8.4	0.82	13.9	85

7.6 Improvement options

It was revealed during the performance evaluation of the pumps that the flow of both the pumps had dropped to 25 m^3/hr and 30 m^3/hr compared to initial flow of around 37.6 m^3/hr. Therefore, for pumping water quantity of 333 m^3 the difference in annual electricity consumption between pumping capacities would be 4320 units. Thus by replacing the pump with flow of 25 m^3/hr with a new pump with same specification as that of the installed booster pump, the plant would accrue annual savings of Rs 16848 annually (@3.90per unit). Details of calculations are given in table 7.6. The tentative investment for the proposed savings would be about Rs 30,000/-.

Table 7.6 Savings from improved delivery of booster pump

Quantity of water pumped in 9 hours	333	m^3
Electricity consumption for a pump with flow rate of 37 m^3/hr to fill 333 m^3/hr	75.6	units
Electricity consumption for a pump with flow rate of 25 M3/HR to fill 333 m^3/hr	90	units
Daily savings	14.4	units
Annual	4320	units
Savings in Rs (@ Rs 3.9/unit)	16848	

8

Compressed Air Systems

There are four numbers of reciprocating type air compressors operating in the containers handling depot. Two identical big size compressors are installed at the side of railway track by the Indian Railway management. Both the rail side compressors are of two stages, lubricating, air cooled type reciprocating type. One compressor runs at a time. The number of small sized compressors installed by CCIL at the rail side, workshop is 1 and 1 respectively. One big, one small compressor at rail side was undertaken for the overhauling, repair work and not in use during the visit of first five days. The small compressor in workshop is installed on the trolley.

The compressed air is generated and supplied for rake testing purpose at two rail side points for the pneumatic brake, controls testing and filling of the rake's in-built reservoirs through one of the two receivers installed separately. The type of air receiver connected with the rail side compressors is vertical. One rake is equipped with 9 units and each unit is with 5 wagons. Therefore, one rake is consists of 45 wagons. The compressed air is generated and supplied for power pack maintenance, tyre filling in the workshop. The wheel movement trolley with small compressor and horizontal air receiver is taken at different points in and around the workshop. The rail side air receiver is fitted with manually operated drain valve to facilitate the water drainage. The mobile air receiver is in the manual mode now for moisture drainage, although it is fitted with the automatically operated drain valve. The operating pressure range at the rail side receivers is 6.4-10.6 kg/cm^2 (g). The operating pressure range at the mobile receiver in workshop is 3.5-14.5 kg/cm^2 (g). The compressors were switched-on and off automatically as the lower and upper pressure limits are achieved. The discharge pipe of two rail side receivers are interconnected at a point few metres away from the receivers. From the receiver, air is supplied through the common underground delivery pipe to the rig testing ridges (RTRs) for wagon testing purpose. The maximum and minimum designed (gauge) pressure of compressed air required at the RTRs (at rail side) is 7.0 kg/cm^2 (g) and 5.5 kg/cm^2 (g) respectively. The operating pressure at the in-built load sensing device (LSD), distribution valve (DV) in each wagon is 1.8 kg/cm^2 (g), 3.5 kg/cm^2 (g) and between 3.5-5.0 kg/cm^2 (g). The compressed air is also used at NIR, Double check valves, etc during the wagon testing process. The minimum designed (gauge) pressure of compressed air required at workshop is 5.5 kg/cm^2 (g).

The detail of air compressors at rail side and workshop are given in Table 8.0.

Table 8.0 Detail of rail side air compressors

No.	Model or Type/ Sr. no	Make	Year of instal-lation	Motor (kW)	Working pressure (kg/cm^2)	Rated FAD	
						cfm	(m^3/ min)
1	LOW1 BOL/ TC 3012	Elgi Equipments Limited.	1991-92	22.0	12.0	120	3.4
2	2HA 2/ 7036	KG Khosla Compressors Ltd.	N. A.	55.0	7 0	600	10.0
3	ME 38	KG Khosla Compressors Ltd.	N. A.	55.0	7 0	600	10.0
4	TC 3000	Elgi Equipments Limited.	1991-92	9 3	16 0	35.3	1.0

Compressor #4 is operating within/ out of shed in the workshop.

8.1 Free air delivery (FAD) test

Compressors are designed to deliver the fix quantity of air at certain pressure. But, due to ageing, wear and tear or poor maintenance compressor may not deliver the specified quantity of air. By performing this test, actual output of a compressor can be assessed. Performance of four reciprocating compressors is given in table8.1.

Table 8.1 Operating parameter of receiver and compressors

Sl. No	Parameter	Comp #1	Comp #2	Comp.#3	Comp.#4
1	[illegible]	1.0	1.0	0.85	0.006
2	Capacity of the interconnecting pipes (m^3)	0.33	0.36	0.05	0.089*
3	Initial pressure (bar abs.)	1 013	1 013	2 157	1.013
4	Final pressure (bar abs.)	11.375	7 257	8 826	15.2
5	Pump-up time (minutes)	10.0	1.821	1.307	1.752
6	Actual FAD (m^3/min)	1.36	4 6	4.53	0.76
7	Design FAD (m^3/min)	3.4	10.0	10.0	1.0
8	Average of actual load on motor (kW)	11.99	37 06	28.93	5.51
9	Sp. power consumption (kW/m^3/min)	8 82	8.05	6.38	7.26

* The reservoir/ receiver is in-built with the compressor. It is located adjacent to the compression cylinder and before the non-return valve (NRV).

If the actual free air delivery, by the above test, comes below 80%, of the rated or designed capacity, the compressor needs overhauling. It is clear from the table that actual FADs of compressor#1, #2, #3 and #4 are 40%, 46%, 45.3% and 76% respectively. The FAD for compressor #1, #2 and #3 is well below where as the same of compressor#4 is slightly below the satisfactory level. Because of this specific power consumption for three compressors is quite high.

8.2 Compressed air leakages

Compressed air leakage forms a major source of energy wastage in the compressed air system. The total length of the compressed air distribution pipeline is about 20 metres and the half of it was below the ground. During the energy audit study, one leakage was noticed from pipe joint on the ground level. It is strongly recommended to identify the leakage points and arrest the same immediately. Though, it is not possible to make compressed air system 100% leak proof, but air leakage above 4-5% in this size of pipeline, certainly, need proper study of the distribution pipeline. The leakage test, to quantify the leakages in the system was carried out during the break period because the compressed air consumption in all systems/ components stopped for a while.

The leakage in the compressed air system can be quantified by running the compressor with all air using equipment shut off. The leakage test was carried out with the compressor #3. The leakage rate in the compressed air line is calculated to be 9%. Even leaving a margin of 4% leakage for untraceable points in the compressed air line below and above the ground, the reduction in electricity consumption achievable in the depot, with plugging out the leakage would be handsome amount annually. The annual electrical energy saving is 6266 kWh, and the corresponding monetary saving would be Rs. 0.244 lacs. The average monetary saving rate for one rake testing was estimated to be Rs 11/-. The details are given in annexure 8.1.

8.2.1 Minimising compressed air leakage

It is difficult to detect air leakage as they cannot be seen and smelt. While large leakages are easily detected by hissing sound generated, it is difficult to detect small leakages, which can only be detected by applying soap solution. Some of the most susceptible points are:

a) threaded pipe joints
b) flange connections
c) valve stems
d) hoses
e) connectors
f) operating valves on pneumatic devices/ tools
g) check valves

The air loss due to leakage can be quite significant depending on the air pressure. Table 8.2.1 gives the leakage through various orifice size and energy wastage at 7 kg/cm^2 (g) and 5 kg/cm^2 (g) air pressure.

Table 8.2.1 Power wastage at different pressures

Orifice dia.	Air leakage (scfm)	Power wasted (kW)
At 7 kg/cm^2 (g) pressure		
1/16" (2 mm)	6.49	1.26
1/8" (3 mm)	26	5.04
1/4" (7 mm)	104	20.19
1/2" (13 mm)	390	75.47
At 5 kg/cm^2 (g) pressure		
1/16" (2 mm)	3.92	0.71
1/8" (3 mm)	8.8	1.60
1/4" (7 mm)	60.5	10.98
1/2" (13 mm)	133.1	24.16

(m^3/min = 39.2 scfm)

8.2 Optimisation of compressed air system

Compressed air from the water/ air-cooled rail side compressors is available in individual reservoir, DV, LSD, NIR, double acting check valves, associated systems and receiver & interconnecting pipes in the depot. Length of pipe, size of pipe, number and type of fittings and valves have been properly considered for the efficient operation of the compressed air system. The sequence of equipments has been arranged to perform the following functions.

1. Removal of particulates as small as three microns with minimum pressure loss using inlet air filters.
2. Reduction of air temperature in compressor #2 and #3 using an intercooler.
3. Reduction of air pressure pulsation and moisture carry-over using a receiver.

As compressed air distribution lines age, corrosion and contamination collect at joints, low areas and underground portion. Sometimes this can move and accumulate forming a blockage at a particular location, which may create pressure drop in the line. The water vapour and liquid removal in the distribution line is done to avoid corrosion by the conventional type compressed air dryer installation after the receiver.

The energy efficiency of a compressed air system can be optimised by maintaining/ installing equipments/ components for proper function. Careful periodical review of the entire system between compressors and compressed air end use machines is essential. All of the systems/ components in the compressed air distribution system should be maintained as per the manufacturer's recommendations. The adequate compressed air is generated from one small compressor for one rake testing. The bigger size compressor operation should be stopped for one rake testing. It should be operated for two rakes testing only.

8.3 Calibration of automatic on-off system, pressure gauges on compressor & receiver

The automatic on/off switch of the compressor #1, #2, #3 and #4 operate at pressure 3.0/ 10.0 kg/cm^2 (g), 7.0/ 8.0 kg/cm^2 (g), 7.0/ 8.0 kg/cm^2 (g) and 3.5/ 14.0 kg/cm^2 (g) respectively. Measurements were carried out after the leakage plug at few selective points in the rail side compressed air distribution lines. The pressure gauge reading on the receiver is always higher than the pressure gauge reading on the compressor #3.

8.4 Use and maintenance of automatic drain valve in air receivers

It was observed that the drain valve fitted with two air receivers of three number rail side reciprocating compressors was manually operated to facilitate the water drainage. Presently, the automatic arrangement of air receiver's drain valve of the mobile reciprocating air compressor is not in working condition. The automatic valve drains the water accumulated in the receiver completely. Plant personnel reported that the manual operation of receiver's drain valve fitted with mobile compressor is done on regular (when bypassing the automatic system) basis. The valve is manually operated. The duration of water drainage is 4-5 minutes at the regular interval of 24 hours. The water drainage through the drain valve fitted with individual air receiver of the compressors was not done during the visit. The frequency of manual drainage of moisture from other receivers is once a day. The manual drainage provision not only passes the water but also allow the compressed air to pass to the atmosphere intermittently. By using the automatic drain valve properly, water would only be allowed to pass accordingly (intermittently in nature), thereby, reducing the wastage of compressed air.

8.5 Inlet air temperature

Two very small sized air intake pipes, filter at two suction ends are located adjacent to the individual cylinder of compressor #1 and #4 respectively. Three compressors, one receiver, associated components are located within the compressor room whereas the fourth compressor, associated components operates within and out of the shed. Temperature of air in the ambient, compressor room/ shed and the individual suction air was measured using thermocouple and it was found that the temperature of the inlet air for the compressor #1, #4 was higher than the ambient temperature. The actual temperature of suction (inside room/ shed) air for four compressors has been given in the table 8.6a.

Table 8.6a Air temperature for suction (inside room/ shed) of compressors

Parameter	*Comp. #1*	*Comp.#2*	*Comp.#3*	*Comp.#4*
Ambient temp. (°C)	30.0	30.0	19.0	29.4
Suction air temp. (°C)	34.7	30.9	20.7	32.3
Difference (°C)	4.7	0.9	1.7	2.9

The actual temperature of suction air in compressor #1 and #4 is above the ambient temperature. The inlet air temperature for compressor #2 and #3 was close to (or almost same as) the ambient temperature. However, care should be taken against any increase in the suction air temperatures. The inlet temperature of air to the compressor is very important, as rise in temperature will increase the energy consumption because of increased volume of air. Thus, lesser the temperature of air at compressor inlet, lesser would be the energy consumption of compressor. The effect of inlet air temperature on compressor performance is given in Table 8.6b.

Table 8.6b Effect of inlet air temperature on compressor performance

S.No	Temperature of intake air (°C)	Volume required to deliver 1000 m^3 at 21°C (m)	Percentage saving/loss related to 21°C
1	5	943	5.7
2	10	982	3.8
3	16	981	1.9
4	21	1000	0
5	27	1020	-1.9
6	32	1040	-3.8
7	37	1060	-5.7
8	43	1080	-7.6
9	49	1100	-9 5

Note: The negative sign in the table indicates energy loss

8.6 Recommendations

Following measures are recommended for the performance improvement of the compressors and compressed air distribution system.

8.6.1 Long term measures

1. Stop the very inefficient compressor #2 and undertake for overhauling immediately. It is also recommended to get other compressors overhauled in phased manner to have the lower energy consumption. The sequence should be for the compressor #3, #1 and #4 respectively. Depot personnel should undertake the overhauling work under the guidance of manufacturer. Proper maintenance has also to be ensured for the FAD of compressor#4 very close/ below the satisfactory level. The check list of the inspection and planned maintenance instruction on air compressors is given in annexure 8.2.

2. Relocate the air inlet (suction pipe with filter) to the compressor #1 and #4 away from the compression cylinder to allow the suction air (temperature and flow) as ambient. The reduction in electricity consumption is achievable in each compressor.

3. Temperature of the air supplied to the suction of the compressors should be monitored periodically to ensure that it is, at least, close or equal to the ambient temperature throughout the compressor operation in all seasons;

4. Install automatic drain valve with receiver fitted with three rail side compressors. Ensure proper maintenance of the automatic drain valve with mobile compressor at workshop;

5. Plug the air leakage immediately. Most of the threaded joints in the pipes below the ground should be made leak proof by welding at the ends. It is recommended to get the entire compressed air distribution system tested with soap solution once in a year;

6. Replace old M. S. pipes by stainless pipe to prevent rusting and pressure drop in the compressed air distribution line. Install the air dryer to prevent moisture from condensing in the distribution pipes system.

8.6.2 House keeping measures

1. Operate one rail side compressor out of three at a time and full load condition;

2. Consult manufacturer/ supplier & reduce the upper setting of pressure switch of compressor No. 1, No. 4 at 8.0 kg/cm^2(g). The annual savings would be about Rs. 0.038 lacs and Rs. 0.07 lacs respectively.

3. Calibrate periodically the pressure gauges/switches fitted with the compressors and receivers to avoid zero error.

4. Bend the pipe fitted with safety valve on receiver with compressor #3 for vertical discharge of air.

9 Air-conditioning systems

9.1 Introduction

Buildings are designed to provide different types of comfort to the occupants but they fail to provide required level of comforts itself. Electrical and mechanical systems are then designed and installed so that occupant can stay in a pleasant indoor environment and show the optimum productivity. Air-conditioning systems are designed to give a constant temperature and humidity level or thermal comfort inside the room irrespective of changing outdoor weather. At CONCOR both central air-conditioning system and unitary (window and split) systems have been installed for space conditioning but at present central system is non-operative and therefore it is not included in the study. Numbers of unitary air-conditioners installed at CONCOR Tughlakabad are given in table 9.1.

Table 9.1 Number of unitary air-conditioning systems

S No.	Area	No of Unitary units
1	Custom computer centre (GF+FF)	24
2	Custom offices (GF+FF)	23
3	CONCOR (GF+FF)	62
4	Business centre	1
5	MTNL	14
6	CONCOR (SF)	54
7	CONCOR (TF)	45
8	Diwan Chand	2
9	Main sub-station & RMG complex	2
10	Export ware house	17
11	Import warehouse	5
12	AM (T) room	1
13	Technical workshop	8

9.2 Air-conditioning system testing

During interaction between TERI & CONCOR officials it was discussed and decided that a sample of installed window air-conditioners which would represent the whole window air-conditioners would be selected for field measurement. The supply air temperature and relative humidity return air temperature and relative humidity, circulating air quantity and compressor motor and condenser fan motor input kW would be measured of all the selected air-conditioners. These data would be analysed and the operating specific power consumption defined as the ration of input compressor kW and cooling produced by air-conditioner (kW/TR) would be calculated. The operating specific power consumption would be compared with the rated specific power consumption and the energy wastage would be estimated.

Approximately 44 window air-conditioners have been selected and various measurements were carried out. The measured data and calculated parameters are shown in tables 9.2a and 9.2b.

Table 9.2a Operating airflow rate of window air-conditioners

S No	Area	Make	Length (in)	Width (in)	Area (ft^2)	air velocity (ft/min)	Airflow rate (ft^3/min)
Technical workshop							
1	Abuthakir office	Amtex	10	6.5	0.45	885	320
2	Walker's office	Amtex	10	6.5	0.45	1178	389
3	Senior GM office	Voltas	24	3	0.50	833	333
4	Senior Manager (Tech)	Amtex	10	6.5	0.45	1065	348
5	GM office-1	Amtex	10	6.5	0.45	1019	332
6	GM office-2	Amtex	10	6.5	0.45	895	323
7	Tech store	Carrier	24	4	0.67	864	439
Accounts & Personnel							
8	AC-1	Carrier	24	4	0.67	898	426
9	AC-2	Voltas	24	3	0.50	921	368
10	AC-3	Amtex	10	6.5	0.45	927	335
11	Senior manager (personnel)	Voltas	24	3	0.50	1140	416
12	AC-4	Voltas	24	3	0.50	1170	428
13	Dy GM (Finanace & Accounts)	Amtex	10	6.5	0.45	1284	428
14	Sr Secretary	Carrier	24	4	0.67	728	388
Bank							
15	AC-1	Voltas	24	3	0.50	924	370
16	AC-2	Voltas	24	3	0.50	918	356
17	AC-3	Voltas	24	3	0.50	965	386
18	Ac-4	Voltas	24	3	0.50	992	397
Engg & Operations							
19	Asstt. Manager (Engg)	Amtex	10	6.5	0.45	951	343
20	Joint GM (Operation)	Amtex	10	6.5	0.45	727	263
Library							
21	AC-1	Voltas	24	3	0.50	928	371
22	AC-2	Carrier	24	4	0.67	830	416
Control Room							
23	AC-1	Amtex	10	6.5	0.45	664	240
24	AC-2	Amtex	10	6.5	0.45	723	261
Samrat shipping							
25	AC-1	Bon-air	9.5	7.5	0.49	1065	382
26	AC-2	Bon-air	9.5	7.5	0.49	1062	381
27	AC-3	Bon-air	9.5	7.5	0.49	1074	386
Service centre (Custom Block)							
28	AC-1	Carrier	24	4	0.67	740	395
29	AC-2	Carrier	24	4	0.67	770	411
30	AC-3	Carrier	24	4	0.67	690	368
31	AC-4	Carrier	24	4	0.67	730	389

S No	Area	Make	Length (in)	Width (in)	Area (ft^2)	air velocity (ft/min)	Airflow rate (ft^3/min)
Export processing (Custom Block)							
32	AC-1	Voltas	24	3	0.50	919	368
33	AC-2	Voltas	24	3	0.50	930	372
34	AC-3	Voltas	24	3	0.50	1010	404
Custom ground floor hall							
35	AC-1	Bon-air	9.5	7.5	0.49	1063	381
36	AC-2	Bon-air	9.5	7.5	0.49	1102	357
37	AC-3	Bon-air	9.5	7.5	0.49	1186	390
38	AC-4	Bon-air	9.5	7.5	0.49	1105	398
Custom Server Room							
39	AC-1	Carrier	24	4	0.67	881	470
40	AC-2	Carrier	24	4	0.67	906	430
Custom UPS room							
41	AC-1	Bon-air	9.5	7.5	0.49	1238	371
42	AC-2	Bon-air	9.5	7.5	0.49	1220	364
43	AC-3	Bon-air	9.5	7.5	0.49	1210	400
44	AC-4	Bon-air	9.5	7.5	0.49	1170	424

Table 9.2b Operating specific power consumption of window air0conditioner

S No	Area	Air flow (ft^3/min)	Supply air temp (°F)	Suppy air RH (%)	Supply air enthalpy (Btu/lb)	Return air temp (°F)	Return air RH (%)	Return air Enthalpy (Btu/lb)	Cooling produced (TR)	Fan motor (kW)	Specific power (kW/TR)
Technical workshop											
1	Abuthakir office	320	43.5	89	16.16	77.1	53.8	30.22	1.69	1.82	1.08
2	Walker's office	389	48.0	90	18.41	77.2	46.1	28.58	1.48	2.4	1.62
3	Senior GM office	333	49.0	89	18.84	75.8	48	28.18	1.17	2.32	1.99
4	Senior Manager (Tech)	348	47.0	90	17.91	75	47.4	27.59	1.26	2.27	1.79
5	GM office-1	332	51.0	89	19.88	80.7	44	30.16	1.28	2.9	2.27
6	GM office-2	323	52.0	88	20.32	85.1	45.1	33.24	1.57	1.97	1.26
7	Tech store	439	45.8	89.5	17.28	77.1	48.2	28.99	1.93	2.54	1.32
Accounts & Personnel											
8	AC-1	426	56.0	87	22.42	80.6	45.5	30.47	1.28	1.93	1.50
9	AC-2	368	50.0	88	19.27	79.2	47.4	30.08	1.49	1.98	1.33
10	AC-3	335	49.0	90	18.92	81.1	44.5	30.53	1.46	2.42	1.66
11	Senior manager (per)	416	48.0	89.7	18.38	75.3	47.8	27.85	1.48	2.31	1.56
12	AC-4	428	53.1	86	20.73	79.8	46.2	30.16	1.51	2.37	1.56
13	Dy GM (Fin & Acc)	428	49.5	91.1	19.26	80.2	46.3	30.43	1.79	2.51	1.40
14	Sr Secretary	388	50.0	90	19.43	78.7	52.3	30.91	1.67	2.14	1.28
Bank											
15	AC-1	370	48.5	88.6	18.55	78.4	46.1	29.29	1.49	2.07	1.39
16	AC-2	356	49.2	88.4	18.89	78.9	45.4	29.42	1.41	1.93	1.37
17	AC-3	386	48.6	89.3	18.66	78.3	46.3	29.27	1.54	2.08	1.35
18	Ac-4	397	49.6	89.2	19.16	77.9	47.2	29.24	1.50	2.06	1.37
Engg & Operations											
19	Asstt. Manager (Engg)	343	47.0	90	17.91	81.4	47.1	31.38	1.73	2.28	1.31
20	Joint GM (Operation)	263	47.0	90	17.91	83.2	43.4	31.54	1.34	1.97	1.47
Library											
21	AC-1	371	54.0	88	21.41	82.8	41.9	30.89	1.32	2.9	2.20
22	AC-2	416	53.2	88.7	21.04	82.1	42.3	30.57	1.49	2.6	1.75
Control Room											
23	AC-1	240	47.0	90	17.91	82.6	39.5	30.13	1.10	2.31	2.10
24	AC-2	261	48.3	89	18.48	81.4	41.3	29.9	1.12	2.03	1.82
Samrat shipping											
25	AC-1	382	49.0	89	18.84	76.8	48.1	28.79	1.43	2.31	1.62
26	AC-2	381	49.2	88.6	18.91	77.4	47.2	28.94	1.43	2.2	1.54

S No	Area	Airflow (ft^3/min)	Supply air temp (° F)	Suppy air RH (%)	Supply air enthalpy (Btu/lb)	Return air temp (° F)	Return air RH (%)	Return air Enthalpy (Btu/lb)	Cooling produced (TR)	Fan motor (kW)	Specific power (kW/TR)
27	AC-3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Service centre (Custom Block)											
28	AC-1	395	48.2	89	18.43	78.4	47.2	29.54	1.64	2.14	1.30
29	AC-2	411	49.7	88.2	19.13	78.2	47.6	29.51	1.60	2.29	1.43
30	AC-3	368	48.3	88.6	18.45	77.9	46.9	29.17	1 48	2.03	1.37
31	AC-4	389	48.5	89.4	18.61	79.1	46.8	29.87	1.64	2.28	1.39
Export processing (Custom Block)											
32	AC-1	368	47.6	89.1	18.14	78.5	46.7	29.49	1.56	2 24	1.43
33	AC-2	372	47.4	88.6	18	77.9	48.1	29.45	1.60	2.21	1.38
34	AC-3	404	48.6	89.7	18.69	79.2	45.9	29.72	1.67	2.43	1.45
Custom ground floor hall											
35	AC-1	381	50.3	89.3	19.53	77.6	46.1	28.82	1.33	2.36	1.78
36	AC-2	357	50.4	89.6	19.61	78.2	46.9	29.35	1 30	2.27	1.74
37	AC-3	390	49.7	88.4	19.15	77.4	46.3	28.74	1.40	2.24	1.60
38	AC-4	398	49.3	89.7	19.05	78.1	47	29.32	1.53	2.18	1.42
Custom Server Room											
39	AC-1	470	50.8	88.4	19.72	78.6	47.1	29.64	1.75	2.49	1.42
40	AC-2	430	50.3	89.4	19.54	78.5	46.9	29.53	1 61	2.47	1.53
Custom UPS room											
41	AC-1	371	51.0	89	19.88	75.7	48.6	28.25	1 17	1.98	1.70
42	AC-2	364	50.9	88.4	19.77	75.9	48.3	28.3	1.16	2.09	1.79
43	AC-3	400	49.8	88.1	19.17	76.7	47.9	28.68	1 43	2.35	1.65
44	AC-4	424	50.1	89.2	19.42	77.2	49	29.22	1.56	2.41	1.55

9.3 Observations

1. It has been observed that at 18 places out of total 44 places the return air temperature was more than 78.5 ° F which means air-conditioners were not able to meet the load in those places.
2. Relative humidity was less than 60% at every place, which was quite expected since measurement was taken during dry summer.
3. The average operating specific energy consumption of the window air-conditioners is calculated to be 1.53 kW/TR as against the rated specific energy consumption of 1.30 kW/TR.

9.4 Factors affect the energy efficiency of packaged and split systems

Refrigerant: Most air conditioning compressors are designed to operate with refrigerant 22, or its equivalent. As the system loses its refrigerant charge, efficiency drops.

Filter/Strainers: These devices are necessary to prevent damaging particles from entering the compressor. When compressors are clogged with dirt, refrigerant flow is restricted with dirt, refrigerant flow is restricted and efficiency is reduced. Frost or moisture on the filter is an indicator of this problem.

Compressor efficiency: In hermetic (sealed) compressors, the motor and compressor are enclosed and sealed as one unit. Recent improvements include more efficient motors and variable speed compressors.

Condensing Coil Area: Usually, the larger the condensing coil, the more efficient it is. Larger coils provide greater heat transfer area, allowing for more heat to be exhausted to the atmosphere. Dirty or bent coil fins reduce the effective heat transfer area.

Computerised Energy Management Systems: These are primarily used for controlling HVAC equipment. Systems can be programmed to turn equipment on and off according to a pre-established schedule. The restaurant can then reach its correct operating temperature at the appropriate time.

9.5 Operations and maintenance

Great energy savings opportunities for offices are possible through controlling the operating time of HVAC equipment. Nevertheless, many occupants continue to leave AC systems on during off time, in the belief that turning them off will not save them enough to justify the effort. Turning systems off when rooms are unoccupied can save a third or more of total AC energy use. Proper operating and maintenance techniques can reduce consumption while the equipment is running. HVAC maintenance includes the following items:

- Cleaning or replacing air filters.
- Regularly checking refrigerant levels
- Cleaning dirt from coil fins
- Obtaining a condensor coil fin comb and straightening coil fins
- Periodically checking refrigerant filters/strainers and
- Where possible, shading the outside unit and allowing plenty of air to circulate around it.

9.6 Estimated potential of energy savings in window air-conditioners

By incorporating above-mentioned practices it may be possible to enhance the efficiency of the installed window air-conditioners to the rated efficiency and this would result energy saving up to 15% of present energy consumption in window air-conditioners or 135450 kWh per year.

ANNEXURES

Connected lighting load & consumption at CONCOR TKD.

			Lamp Wattage	Lamp+Choke Wattage	Nos	kW	Hrs	kVAH/d	Days	KVAH/y
Admin sub-station										
1	Custom computer centre									
	(GF+FF)	TL-single	40	52.5	2	0.105	24	2.2	365	818
		TL-double	80	105	95	9.975	24	212.8	365	77672
2	Custom officers									
	(GF+FF)	TL-single	40	52.5	29	1.5225	10	13.5	300	4060
		TL-double	80	105	131	13.755	10	122.3	300	36680
3	Concor									
	(GF+FF+priva	TL-single	40	52.5	29	1.5225	10	13.5	300	4060
		TL-double	80	105	131	13.755	10	122.3	300	36680
4	MTNL									
		TL-single	40	52.5	2	0.105	24	2.2	300	672
		TL-double	80	105	35	3.675	24	78.4	300	23520
5	Second Floor									
		TL-single	40	52.5	217	11.393	10	101.3	300	30380
		TL-double	80	105	130	13.65	10	121.3	300	36400
6	Third Floor									
		TL-single	40	52.5	286	15.015	10	133.5	300	40040
		TL-double	80	105	95	9.975	10	88.7	300	26600
7	In/out gate/roof/parking									
		TL-single	40	52.5	119	6.2475	10	55.5	365	20270
		TL-double	80	105	2	0.21	10	1.9	365	681
Main/RMG sub-station										
1	Main/RMG complex									
		TL-single	40	52.5	4	0.21	12	2.2	365	818
		TL-double	80	105	42	4.41	12	47.0	365	17170
2	C&W Rly complex									
		TL-single	40	52.5	0	0	12	0.0	365	
		TL-double	80	105	37	3.885	12	41.4	365	15126
3	ECR room									
		TL-single	40	52.5	5	0.2625	12	2.8	365	1022
		TL-double	80	105	11	1.155	12	12.3	365	4497
4	DVB rec. st. room									
		TL-single	40	52.5	4	0.21	12	2.2	365	818
		TL-double	80	105	6	0.63	12	6.7	365	2453
Workshop sub-station										
1	Technical workshop									
		TL-single	40	52.5	22	1.155	10	10.3	300	3080
		TL-double	80	105	76	7.98	10	70.9	300	21280
2	Pump house									
		TL-single	40	52.5	4	0.21	12	2.2	365	818
Warehouse sub-station										
1	Export warehouse									
		TL-single	40	52.5	5	0.2625	12	2.8	300	840
		TL-double	80	105	100	10.5	12	112.0	300	33600
2	Import warehouse									
		TL-single	40	52.5	8	0.42	12	4.5	300	1344
		TL-double	80	105	32	3.36	12	35.8	300	10752

3	Others									46536
		TL-single	40	52.5	20	1.05	12	11.2	300	3360
		TL-double	80	105	20	2.1	12	22.4	300	6720

HPSV Lighting

			Lamp Wattage	Lamp+Choke Wattage	Nos	kW	Hrs	kVAH/d	Days	KVAH/y
Admin sub-station										
1	MTNL	HPHV	150	170	4	0.68	12	7.3	365	2647
2	In/out gate/roof/parking		250	280	31	8.68	12	92.6	365	33794
			400	445	26	11.57	12	123.4	365	45046
3	Tower-1	HPSV	400	445	36	16.02	12	170.9	365	62371
4	Tower-2	HPSV	400	445	36	16.02	12	170.9	365	62371
5	Tower-6	HPSV	400	445	28	12.46	12	132.9	365	48511
6	Tower-7	HPSV	400	445	28	12.46	12	132.9	365	48511
7	Tower-8	HPSV	400	445	36	16.02	12	170.9	365	62371
Main/RMG sub-station										
1	Main/RMG con	HPHV	150	170	2	0.34	12	3.6	365	1324
			250	280	7	1.96	12	20.9	365	7631
2	ECR room	HPHV	150	170	4	0.68	12	7.3	365	2647
3	DVB rec. st. ro	HPHV	150	170	2	0.34	12	3.6	365	1324
4	C&W Rly comp	MH	400	427	7	2.989	12	31.9	365	11637
5	Tower-3	HPSV	400	445	36	16.02	12	170.9	365	62371
6	Tower-4	HPSV	400	445	36	16.02	12	170.9	365	62371
7	Tower-5	HPSV	400	445	36	16.02	12	170.9	365	62371
8	Tower-16	HPSV	400	445	20	8.9	12	94.9	365	34651
9	Tower-17	HPSV	400	445	20	8.9	12	94.9	365	34651
10	Tower-18	HPSV	400	445	20	8.9	12	94.9	365	34651
11	Tower-19	HPSV	400	445	20	8.9	12	94.9	365	34651
Workshop sub-station										
1	Technical	HPHV	150	170	24	4.08	12	43.5	365	1588
			250	280	2	0.56	12	6.0	365	218
2	Pump house	HPHV	400	445	20	8.9	12	94.9	365	3465
3	Tower-12	HPSV	400	445	20	8.9	12	94.9	365	3465
Warehouse substation										
1	Export	HPHV	150	170	320	54.4	10	483.6	365	17649
			250	280	15	4.2	10	37.3	365	1362
			400	445	26	11.57	10	102.8	365	3753
2	Import	HPHV	150	170	168	28.56	10	253.9	365	9266
			250	280	30	8.4	10	74.7	365	2725
			400	445	23	10.235	10	91.0	365	3320
3	Bonded	HPHV	150	170	54	9.18	10	81.6	365	2978
			400	445	23	10.235	10	91.0	365	3320
4	Tower-9	HPSV	400	445	36	16.02	12	170.9	365	6237
5	Tower-10	HPSV	400	445	28	12.46	12	132.9	365	4851
6	Tower-11	HPSV	400	445	28	12.46	12	132.9	365	4851
7	Tower-13	HPSV	400	445	28	12.46	12	132.9	365	4851
8	Tower-14	HPSV	400	445	28	12.46	12	132.9	365	4851
9	Tower-15	HPSV	400	445	28	12.46	12	132.9	365	4851
10	Tower-20	HPSV	400	445	20	8.9	12	94.9	365	3465
11	Tower-21	HPSV	400	445	20	8.9	12	94.9	365	3465

Lighting Annexture

Measured Lighting Levels in Admin Block

Level	Room No/ Description	Light levels Lux	Lighting equipment	Lamps/ Fittings	Fittings Nos.	Lamp Type	Total lamp (Watt)	Faulty lamps
GF	Admin subsat	60, 40, 500	SM	2	13	FL	40	3
GF	Bank	60,,100,120	SM	2	17	FL	40	0
GF	RM3							
	Secretary	70	WM	1	3	FL	40	0
	Officer room	120	SM	2	4	FL	40	0
GF	RM4	175	SM	2	6	FL	40	0
GF	RM5	120	SM	2	3	FL	40	0
GF	RM6A							
	Secretary	150	SM	2	2	FL	40	0
	Officer room	160	SM	2	2	FL	40	0
GF	RM6B	240	SM	2	6	FL	40	0
GF	RM7&8							
	Cabin	120	SM	2	2	FL	40	0
	Staff area	80	SM	2	6	FL	40	0
	UPS room	80	WM	1	1	FL	40	0
	Other area	90	SM	2	6	FL	40	0
GF	RM9							
	Secretary cab	110	SM	2	2	FL	40	0
	Officer cabin	105	SM	2	2	FL	40	0
	Staff room	100,140	SM	2	8	FL	40	2
	Other area	105	SM	2	2	FL	40	0
GF	RM10							
	Staff room	100	SM	2	24	FL	40	7
	Cabin-1	110	SM	2	2	FL	40	0
	Cabin-2	115	SM	2	2	FL	40	0
	Cabin-3	80	SM	2	2	FL	40	2
	Cabin-4	120	SM	2	3	FL	40	0
GF	RM11							
	Staff room	120	SM	2	10	FL	40	4
	Other area	90	SM	2	4	FL	40	0
	Cabin	70	SM	2	1	FL	40	1
GF	RM12	100	SM	2	6	FL	40	0
IF	RM130	130	SM	2	5	FL	40	0
IF	RM131	140	SM	2	3	FL	40	0
IF	RM132	150	SM	2	7	FL	40	0
IF	RM133							
	Secretary roo	185	SM	2	3	FL	40	0
	Officer room	180	SM	2	4	FL	40	0
IF	RM106A	100,180	SM	2	6	FL	40	1
IF	RM106B	80,100,120	SM	2	6	FL	40	0
IF	RM106C							
	Room	125	SM	2	4	FL	40	0
	Library	120	SM	2	1	FL	40	0
IF	RM105	90,100,120	SM	2	6	FL	40	1
IVF	Astt Comd ro	125	SM	2	3	FL	40	0
			WM	2	1	FL	40	0
IVF	Accont sectio	420	SM	1	2	FL	40	0
IVF	CISF office	150	SM	2	3	FL	40	0

IVF	CISF control	120	SM	2	5	FL	40	0
			WM	2	1	FL	40	0
IVF	Hall used with conferences		SM	2	9	FL	40	0
			CR	1	8	GLS	100	0
IVF	Conference hall							
	Entrance lobby		CR	2	2	FL	40	0
	Main hall	160,175	SM	2	16	FL	40	0
				1	16	LVH	50	0
All	Stairs		SM	1	15	FL	40	0
IIF	RM134A	200	SM	2	3	FL	40	0
IIF	RM134B	160	SM	2	3	FL	40	0
IIF	RM101	60	SM	2	4	FL	40	0
IIF			SM	1	2	FL	40	0
IIF	RM102	140	SM	2	6	FL	40	1
IIF	RM103A	160	W&CM	1	6	FL	40	0
IIF	RM103B	140,200	SM	4	5	FL	35	2
IIF	RM104	80	W&CM	1	6	FL	40	0
IIF	RM107	120,150	SM	2	11	FL	40	0
				1	21	CFL	15	0
IIF	RM108A	40	SM	2	2	FL	40	0
IIF	RM108B	80,150	SM	2	2	FL	40	0
IIF	RM109A	120,125,200	SM	2	4	FL	40	0
IIF	RM109B	50	SM	1	6	FL	40	0
IIF	RM110	220	SM	2	6	FL	40	0
IIF	RM106A	60	SM	2	7	FL	40	11
IIF	RM106B	90	SM	2	11	FL	40	0
IIIF	RM201/202	30,50	SM	2	10	FL	40	2
IIIF			SM	1	6	FL	40	0
IIIF	RM203	100,110	SM	2	5	FL	40	1
			SM	1	1	FL	40	0
IIIF	RM204	80	SM	2	5	FL	40	2
IIIF	RM247	320	SM	2	2	FL	40	2
IIIF	RM250	150	SM	1	2	FL	40	2
IIIF	RM251	160	SM	2	4	FL	40	0
IIIF	RM252	160	SM	2	2	FL	40	2
IIIF	RM253	80	SM	2	1	FL	40	0
				1	1	FL	40	0
IIIF	RM254	30	SM	2	1	FL	40	0
IIIF	RM255	80,180	SM	2	2	FL	40	0
IIIF	RM256	60	SM	2	1	FL	40	2
				1	2	FL	40	0
				1	2	FL	35	2
IIIF	RM257	180	SM	2	3	FL	40	0
IIIF	RM208	100	SM	2	7	FL	40	4
IIIF	RM209	40	SM	2	2	FL	40	2
				1	4	GLS	40	4
IIIF	RM210	75	SM	1	4	FL	40	0
IIIF	RM206A	235	SM	1	4	FL	40	0
				1	2	GLS	100	0
IIIF	RM205	160	SM	2	6	FL	40	6
				1	2	FL	40	0
IVF	RM305	160	CR	2	12	FL	40	5
				1	1	FL	40	0
IVF	RM304	60	CR	1	4	GLS	100	4
IVF	RM303	65	SM	1	4	FL	40	0
All	Stairs		SM	1	20	FL	40	0

Lighting Annexture

Measured lighting levels in Custom Block

Level	Room No/ Description	Light levels Lux	Lighting equipment	Lamps/ Fittings	Fittings Nos.	Lamp Type	Total lamp (Watt)	Faulty lamps
GF	Business cen	20,40	SF	1	2	FL	40	1
GF	Drivers roon	60	SF	1	2	FL	40	0
GF	RM13	75,125	SF	2	5	FL	40	3
				1	1	FL	40	0
GF	RM14	150	SF	2	6	FL	40	0
				1	1	FL	40	0
GF	RM15	100,120	SF	2	6	FL	40	2
GF	RM16	60	SF	2	6	FL	40	8
GF	RM17	120	SF	2	5	FL	40	1
GF	RM18	140	SF	2	6	FL	40	0
GF	RM19	130	SF	2	6	FL	40	0
GF	RM20	150	SF	2	6	FL	40	0
GF	RM21	160	SF	2	6	FL	40	1
GF	RM22	180	SF	2	6	FL	40	1
GF	RM23	90	SF	2	3	FL	40	1
GF	RM24-27	40,60	SF	2	18	FL	40	7
		140,175	CR	2	18	FL	40	0
		160	CR	2	8	FL	40	1
GF	RM28	150	SM	2	8	FL	40	0
IF	RM111	50	SM	2	6	FL	40	4
IF	RM112	110,150	SM	2	5	FL	40	0
IF	RM113	100	SM	2	6	FL	40	6
IF	RM114	125	SM	2	6	FL	40	4
IF	RM115	100	SM	2	2	FL	40	2
		150	SM	2	9	FL	40	0
IF	RM117	160	SM	2	6	FL	40	1
IF	RM118	150	SM	2	6	FL	40	0
IF	RM119	310	CR	2	8	FL	40	0
IF	RM116	200,160,210	CR	2	45	FL	40	26
IF	RM115A	120	SM	2	8	FL	40	0
IIF	RM224/225	120/100	H	1	18	FL	40	0
IIF	RM226	150	SM	1	4	FL	40	0
IIF	RM227	110	CR	1	26	CFL	15	3
			CR	4	4	FL	35	4
IIF	RM228	100	SM	1	2	FL	40	0
IIF	RM229	50	SM	2	4	FL	40	7
				1	1	FL	40	1
IIIF	RM230	90,80,120	CR	2	4	CFL	15	0
				2	2	FL	40	0
				2	4	CFL	15	5
IIIF	RM232	80,140	SM	2	1	FL	40	1
			SM	1	4	FL	40	0
IIIF	RM232	40	SM	2	2	FL	40	4
IIIF	RM233	75	SM	2	1	FL	40	1
			SM	2	1	FL	40	0
IIIF	RM234	50	SM	2	1	FL	40	1
				1	2	FL	40	0
IIIF	RM235	50	SM	2	1	FL	40	0

				1	1	FL	40	0
IIIF	RM236	30	SM	2	1	FL	40	1
				1	3	FL	40	1
IIIF	RM237B	50	SM	2	1	FL	40	1
IIIF	RM237A	200	CR	2	5	CFL	40	4
IIIF	RM239	140	SM	2	2	FL	40	1
				1	3	FL	40	0
IIIF	RM240	100	SM	1	3	FL	40	1
IIIF	RM241	75	SM	2	1	FL	40	0
IIIF	RM242	80	SM	2	2	FL	40	2
IIIF	RM243	85	SM	2	1	FL	40	2
IIIF	RM244	75	SM	2	1	FL	40	2
IIIF	RM248	240	SM	2	2	FL	40	1
				1	2	FL	40	1
IIIF	RM247	90	SM	2	1	FL	40	0
				1	7	FL	40	7
IIIF	RM223	40,80	SM	2	4	FL	40	5
IIIF	RM221	100	CR	1	7	GLS	60	0
IIIF	RM220	80	SM	2	9	FL	40	14
IIIF	RM219B	120,140	SM	2	4	FL	40	0
				1	2	FL	35	0
				1	1	FL	35	0
IIIF	RM219C	60	SM	1	1	FL	40	0
IIIF	RM216	70	SM	2	3	FL	40	0
				1	1	FL	35	1
IIIF	RM215	20	SM	1	3	FL	40	2
IIIF	RM219A	150	CR	2	5	FL	40	0
IIIF	RM214A/B	75,180	SM	1	5	FL	40	1
IIIF	RM213	150	SM	1	8	FL	40	7
IIIF	RM218	90	SM	1	7	FL	40	0
IIIF	RM212	200	SM	1	3	FL	40	0
				1	6	GLS	100	4
IIIF	RM205A	40	SM	2	6	FL	40	0
				1	4	FL	35	2
				1	4	CFL	15	4
IIIF	RM217	NA	SM	2	6	FL	40	12
IVF	RM308	100,180	WM	1	11	FL	40	0
IVF	RM314	120	CR	2	2	CFL	15	0
				1	7	CFL	15	5
IVF	RM309	100	SM	1	8	FL	40	2
IVF	RM310	90	SM	1	6	FL	40	5
IVF	RM311	110	SM	2	2	FL	40	0
				1	3	FL	40	0
IVF	RM312	90	WM	1	6	FL	40	0
IVF	RM313	80,200	SM	1	7	FL	40	1
IVF	RM313A	40	SM	2	2	FL	40	0
IVF	RM318	30,100	SM	1	6	FL	40	2
IVF	RM320	80	SM	1	4	FL	40	0
IVF	RM342	110	SM	2	1	FL	40	0
IVF	RM343	110	SM	2	1	FL	40	2
				1	1	FL	40	1
IVF	RM344	75	SM	2	2	FL	40	2
IVF	RM345	80	SM	2	1	FL	40	1
				1	1	FL	40	1
IVF	RM341	50	SM	2	1	FL	40	1
IVF	RM340	200	SM	2	2	FL	40	2

IVF	RM338	120	SM	2	1	FL	40	0
				1	1	FL	40	0
				1	3	GLS	40	0
IVF	RM337	100,140	SM	1	2	FL	40	0
IVF	RM336	50,210	SM	1	2	FL	40	1
				1	1	FL	40	1
IVF	RM334	450	SM	2	1	FL	40	0
				1	4	FL	40	0
IVF	RM332	50	SM	1	3	FL	40	0
IVF	RM331	70	SM	2	2	FL	40	2
IVF	RM330	50	SM	2	1	FL	40	1
				1	3	FL	40	0
IVF	RM329	130	SM	2	2	FL	40	0
				1	5	FL	35	1
IVF	RM328	80	SM	1	2	FL	40	0
				1	2	CFL	15	1
IVF	RM325A	160	SM	1	8	FL	40	4
IVF	RM321	50,120	SM	2	2	FL	40	0
				1	6	FL	35	0
IVF	RM325B	40	SM	1	6	FL	40	0
				1	2	FL	35	0
				1	1	CFL	15	1
IVF	RM326	60	CR	2	5	FL	40	0
				1	3	CFL	15	2
IVF	RM327A	100	CR	1	11	CFL	15	1
IVF	RM327B	140	SM	1	5	FL	40	1
IVF	RM324	50	SM	2	4	FL	40	2
IVF	RM323	100	SM	1	6	FL	40	0
IVF	RM322	100	SM	1	8	FL	40	1
ALL	STAIRS	40,80	SM	1	15	FL	40	0

Lighting Annexture

Replace electromagnetic choke with super power saver ballasts

		Lamp	L+B	L+LL	Nos	Saved	Opt.	Saved	No. of	Saved	Cost	Invest	Payback
		W	W	W		kW	Hrs	kVAh/d	Days/y	kVAh/y	Rs	Rs	Yrs
Admin sub-station													
1	Custom computer centre												
GF	Single	40	52.5	44.5	2	0.016	24	0.3	365	125	497	600	1.2
FF	Double	80	105	89	95	1.52	24	32.4	365	11836	47225	57000	1.2
2	Custom offices												
GF	Single	40	52.5	44.5	29	0.232	10	2.1	300	619	2468	8700	3.5
FF	Double	80	105	89	131	2.096	10	18.6	300	5589	22301	78600	3.5
3	Concor												
GF	Single	40	52.5	44.5	29	0.232	10	2.1	300	619	2468	8700	3.5
FF	Double	80	105	89	131	2.096	10	18.6	300	5589	22301	78600	3.5
4	MTNL												
	Single	40	52.5	44.5	2	0.016	24	0.3	300	102	409	600	1.5
	Double	80	105	89	35	0.56	24	11.9	300	3584	14300	21000	1.5
5	Second Floor												
	Single	40	52.5	44.5	217	1.736	10	15.4	300	4629	18471	65100	3.5
	Double	80	105	89	130	2.08	10	18.5	300	5547	22131	78000	3.5
6	Third Floor												
	Single	40	52.5	44.5	286	2.288	10	20.3	300	6101	24344	85800	3.5
	Double	80	105	89	95	1.52	10	13.5	300	4053	16173	57000	3.5
7	In/out gate/roof/parking												
	Single	40	52.5	44.5	119	0.952	10	8.5	365	3089	12324	35700	2.9
	Double	80	105	89	2	0.032	10	0.3	365	104	414	1200	2.9
Main/RMG sub-station													
1	Main/RMG complex												
	Single	40	52.5	44.5	4	0.032	12	0.3	365	125	497	1200	2.4
	Double	80	105	89	42	0.672	12	7.2	365	2616	10439	25200	2.4
2	C&W Rly complex												
	Single	40	52.5	44.5	0	0	12	0.0	365	0	0	0	
	Double	80	105	89	37	0.592	12	6.3	365	2305	9196	22200	2.4
3	ECR room												
	Single	40	52.5	44.5	5	0.04	12	0.4	365	156	621	1500	2.4
	Double	80	105	89	11	0.176	12	1.9	365	685	2734	6600	2.4
4	DVB rec. st. room												
	Single	40	52.5	44.5	4	0.032	12	0.3	365	125	497	1200	2.4
	Double	80	105	89	6	0.096	12	1.0	365	374	1491	3600	2.4
Workshop sub-station													
1	Technical workshop												
	Single	40	52.5	44.5	22	0.176	10	1.6	300	469	1873	6600	3.5
	Double	80	105	89	76	1.216	10	10.8	300	3243	12938	45600	3.5
2	Pump house										0		
	Single	40	52.5	44.5	4	0.032	12	0.3	365	125	497	1200	2.4
	Double	80	105	89	0	0	12	0.0	365	0	0	0	
Warehouse sub-station													
1	Export warehouse												
	Single	40	52.5	44.5	5	0.04	12	0.4	300	128	511	1500	2.9
	Double	80	105	89	100	1.6	12	17.1	300	5120	20429	60000	2.9

2	Import warehouse												
		Single	40	52.5	44.5	8	0 064	12	0.7	300	205	817	2400	2.9
		Double	80	105	89	32	0.512	12	5 5	300	1638	6537	19200	2.9
3	Bonded warehouse												
		Single	40	52.5	44.5	0	0	12	0.0	300	0	0	0	
		Double	80	105	89	0	0	12	0.0	300	0	0	0	
4	Others												
		Single	40	52.5	44.5	20	0.16	12	1.7	300	512	2043	6000	2.9
		Double	80	105	89	20	0.32	12	3.4	300	1024	4086	12000	2.9
							21.136		221 9		**70435**	**281035**	792600	2.8

Lighting Annexture

Replace electromagnetic choke with electronic choke

			Lamp	L+B	L+EC	Nos	Opt.	Saved	Saved	Days	Saved	Cost	Invest	Payback
			W	W	W		Hrs	kW	kVAH	No.	kVAh/y	Rs	Rs	Yrs
Admin sub-station														
1	Custom computer centre													
	GF	Single	40	52.5	43	2	0	24	0.4	365	148	590	800	1.4
	FF	Double	80	105	86	95	1.8	24	38.5	365	14055	56079	66500	1.2
2	Custom offices													
	GF	Single	40	52.5	43	29	0.3	10	2.4	300	735	2931	11600	4.0
	FF	Double	80	105	86	131	2.5	10	22.1	300	6637	26483	91700	3.5
3	Concor													
	GF	Single	40	52.5	43	29	0.3	10	2.4	300	735	2931	11600	4.0
	FF	Double	80	105	86	131	2.5	10	22.1	300	6637	26483	91700	3.5
4	MTNL													
		Single	40	52.5	43	2	0	24	0.4	300	122	485	800	1.6
		Double	80	105	86	35	0.7	24	14.2	300	4256	16981	24500	1.4
5	Second Floor													
		Single	40	52.5	43	217	2.1	10	18.3	300	5497	21934	86800	4.0
		Double	80	105	86	130	2.5	10	22.0	300	6587	26281	91000	3.5
6	Third Floor													
		Single	40	52.5	43	286	2.7	10	24.2	300	7245	28909	114400	4.0
		Double	80	105	86	95	1.8	10	16.0	300	4813	19205	66500	3.5
7	In/out gate/roof/parking													
		Single	40	52.5	43	119	1.1	10	10.0	365	3668	14635	47600	3.3
		Double	80	105	86	2	0	10	0.3	365	123	492	1400	2.8
Main/RMG sub-station														
1	Main/RMG complex													
		Single	40	52.5	43	4	0	12	0.4	365	148	590	1600	2.7
		Double	80	105	86	42	0.8	12	8.5	365	3107	12396	29400	2.4
2	C&W Rly complex													
		Single	40	52.5	43	0	0	12	0.0	365	0	0	0	
		Double	80	105	86	37	0.7	12	7.5	365	2737	10921	25900	2.4
3	ECR room													
		Single	40	52.5	43	5	0	12	0.5	365	185	738	2000	2.7
		Double	80	105	86	11	0.2	12	2.2	365	814	3247	7700	2.4
4	DVB rec. st. room													
		Single	40	52.5	43	4	0	12	0.4	365	148	590	1600	2.7
		Double	80	105	86	6	0.1	12	1.2	365	444	1771	4200	2.4
Workshop sub-station														
1	Technical workshop													
		Single	40	52.5	43	22	0.2	10	1.9	300	557	2224	8800	4.0
		Double	80	105	86	76	1.4	10	12.8	300	3851	15364	53200	3.5
2	Pump house											0		
		Single	40	52.5	43	4	0	12	0.4	365	148	590	1600	2.7
		Double	80	105	86	0	0	12	0.0	365	0	0	0	
Warehouse sub-station														
1	Export warehouse													
		Single	40	52.5	43	5	0	12	0.5	300	152	606	2000	3.3
		Double	80	105	86	100	1.9	12	20.3	300	6080	24259	70000	2.9
2	Import warehouse													
		Single	40	52.5	43	8	0.1	12	0.8	300	243	970	3200	3.3

		Double	80	105	86	32	0.6	12	6.5	300	1946	7763	22400	2.9
3	Bonded warehouse													
		Single	40	52.5	43	0	0	12	0.0	300	0	0	0	
		Double	80	105	86	0	0	12	0.0	300	0	0	0	
4	Others													
		Single	40	52.5	43	20	0.2	12	2.0	300	608	2426	8000	3.3
		Double	80	105	86	20	0.4	12	4.1	300	1216	4852	14000	2.9
							25		263.5		**83641**	**333729**	962500	2.9

Lighting Annexture

Replace existing fluorescent lamps with T-5

			Lamp	L+B	L+EC	Nos	Opt.	Saved	Saved	Days	Saved	Cost	Invest	Payback
			W	W	W		Hrs	kW	kVAH	No.	kVAh/y	Rs	Rs	Yrs
Admin sub-station														
1	Custom computer centre													
	GF	Single	40	52.5	29	2	24	0.047	1.0	365	366	1460	1700	1.2
	FF	Double	80	105	58	95	24	4.465	95.3	365	34767	138722	161500	1.2
2	Custom offices													
	GF	Single	40	52.5	29	29	10	0.6815	6.1	300	1817	7251	24650	3.4
	FF	Double	80	105	58	131	10	6.157	54.7	300	16419	65510	222700	3.4
3	Concor													
	GF	Single	40	52.5	29	29	10	0.6815	6.1	300	1817	7251	24650	3.4
	FF	Double	80	105	58	131	10	6.157	54.7	300	16419	65510	222700	3.4
4	MTNL													
		Single	40	52.5	29	2	24	0.047	1.0	300	301	1200	1700	1.4
		Double	80	105	58	35	24	1.645	35.1	300	10528	42007	59500	1.4
5	Second Floor													
		Single	40	52.5	29	217	10	5.0995	45.3	300	13599	54259	184450	3.4
		Double	80	105	58	130	10	6.11	54.3	300	16293	65010	221000	3.4
6	Third Floor													
		Single	40	52.5	29	286	10	6.721	59.7	300	17923	71511	243100	3.4
		Double	80	105	58	95	10	4.465	39.7	300	11907	47508	161500	3.4
7	In/out gate/roof/parking													
		Single	40	52.5	29	119	10	2.7965	24.9	365	9073	36202	101150	2.8
		Double	80	105	58	2	10	0.094	0.8	365	305	1217	3400	2.8
Main/RMG sub-station														
1	Main/RMG complex													
		Single	40	52.5	29	4	12	0.094	1.0	365	366	1460	3400	2.3
		Double	80	105	58	42	12	1.974	21.1	365	7685	30665	71400	2.3
2	C&W Rly complex													
		Single	40	52.5	29	0	12	0	0.0	365	0	0	0	
		Double	80	105	58	37	12	1.739	18.5	365	6771	27014	62900	2.3
3	ECR room													
		Single	40	52.5	29	5	12	0.1175	1.3	365	457	1825	4250	2.3
		Double	80	105	58	11	12	0.517	5.5	365	2013	8031	18700	2.3
4	DVB rec. st. room													
		Single	40	52.5	29	4	12	0.094	1.0	365	366	1460	3400	2.3
		Double	80	105	58	6	12	0.282	3.0	365	1098	4381	10200	2.3
Workshop sub-station														
1	Technical workshop													
		Single	40	52.5	29	22	10	0.517	4.6	300	1379	5501	18700	3.4
		Double	80	105	58	76	10	3.572	31.8	300	9525	38006	129200	3.4
2	Pump house											0		
		Single	40	52.5	29	4	12	0.094	1.0	365	366	1460	3400	2.3
		Double	80	105	58	0	12	0	0.0	365	0	0	0	
Warehouse substation														
1	Export warehouse													
		Single	40	52.5	29	5	12	0.1175	1.3	300	376	1500	4250	2.8
		Double	80	105	58	100	12	4.7	50.1	300	15040	60010	170000	2.8

2	Import warehouse													
		Single	40	52.5	29	8	12	0.188	2.0	300	602	2400	6800	2.8
		Double	80	105	58	32	12	1.504	16.0	300	4813	19203	54400	2.8
3	Bonded warehouse													
		Single	40	52.5	29	0	12	0	0.0	300	0	0	0	
		Double	80	105	58	0	12	0	0.0	300	0	0	0	
4	Others													
		Single	40	52.5	29	20	12	0.47	5.0	300	1504	6001	17000	2.8
		Double	80	105	58	20	12	0.94	10.0	300	3008	12002	34000	2.8
								62.087	651.9		**206902**	**825540**	2E+06	2.7

Lighting Annexture

Replace existing timers with Nature switch

Sub-station	Tower No	Lamp	Lamp	L+B	Nos	Load	Hrs	Load	kVAh/y	Cost	Invest	Payback
		Type	W	W		kW		KVA		Rs	Rs	Yrs
Warehouse												
	Tower-9	HPSV	400	445	36	16	12	17.80	6497	25923	15000	0.58
	Tower-10	HPSV	400	445	28	12.5	12	13.84	5053	20162	15000	0.74
	Tower-11	HPSV	400	445	28	12.5	12	13.84	5053	20162	15000	0.74
	Tower-13	HPSV	400	445	28	12.5	12	13.84	5053	20162	15000	0.74
	Tower-14	HPSV	400	445	28	12.5	12	13.84	5053	20162	15000	0.74
	Tower-15	HPSV	400	445	28	12.5	12	13.84	5053	20162	15000	0.74
	Tower-20	HPSV	400	445	20	8.9	12	9.89	3609	14402	15000	1.04
	Tower-21	HPSV	400	445	20	8.9	12	9.89	3609	14402	15000	1.04
Workshop												
	Tower-12	HPSV	400	445	20	8.9	12	9.89	3609	14402	15000	1.04
Main/RMG												
	Tower-3	HPSV	400	445	36	16	12	17.80	6497	25923	15000	0.58
	Tower-4	HPSV	400	445	36	16	12	17.80	6497	25923	15000	0.58
	Tower-5	HPSV	400	445	36	16	12	17.80	6497	25923	15000	0.58
	Tower-16	HPSV	400	445	20	8.9	12	9.89	3609	14402	15000	1.04
	Tower-17	HPSV	400	445	20	8.9	12	9.89	3609	14402	15000	1.04
	Tower-18	HPSV	400	445	20	8.9	12	9.89	3609	14402	15000	1.04
	Tower-19	HPSV	400	445	20	8.9	12	9.89	3609	14402	15000	1.04
Admin												
	Tower-1	HPSV	400	445	36	16	12	17.80	6497	25923	15000	0.58
	Tower-2	HPSV	400	445	36	16	12	17.80	6497	25923	15000	0.58
	Tower-6	HPSV	400	445	28	12.5	12	13.84	5053	20162	15000	0.74
	Tower-7	HPSV	400	445	28	12.5	12	13.84	5053	20162	15000	0.74
	Tower-8	HPSV	400	445	36	16	12	17.80	6497	25923	15000	0.58
						262		291	106118	423409	315000	0.74

Lighting Annexture

Install trend setter on HM Tower Lighting

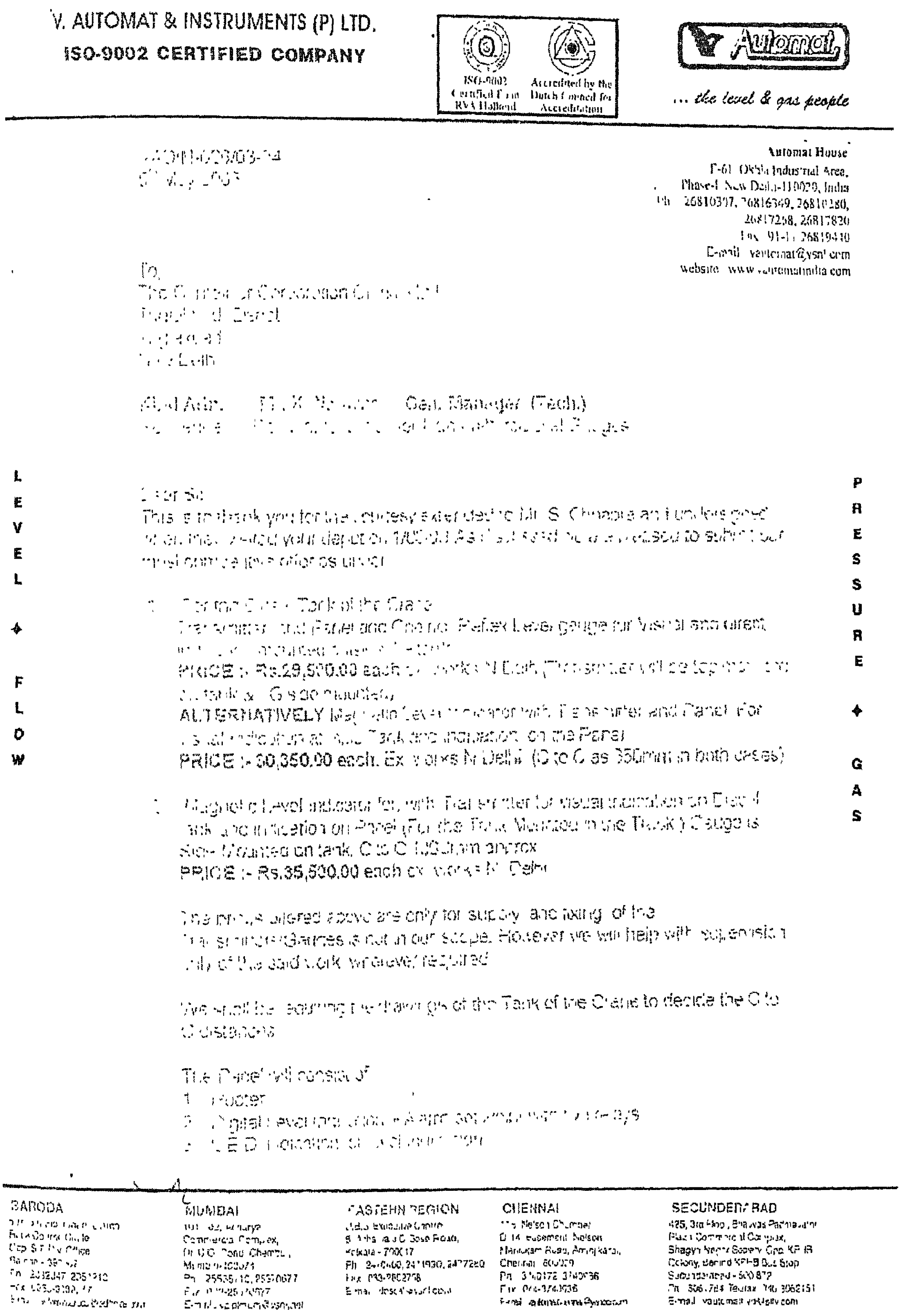
Sub-station	Tower No	Lamp	L+B	Nos	Load	Ope.	KVAH	Load	Load	Saving	Cost	Invest	Payback
		W	W		kW	Hrs/d		Initial	Final	kVAh/y	Rs	Rs	years
Warehouse													
	Tower-9	400	445	36	16	12	170.88	16.02	9.90	5606	48293	40050	0.83
	Tower-10	400	445	28	12.5	12	132.91	12.46	7.70	4361	37561	31150	0.83
	Tower-11	400	445	28	12.5	12	132.91	12.46	7.70	4361	37561	31150	0.83
	Tower-13	400	445	28	12.5	12	132.91	12.46	7.70	4361	37561	31150	0.83
	Tower-14	400	445	28	12.5	12	132.91	12.46	7.70	4361	37561	31150	0.83
	Tower-15	400	445	28	12.5	12	132.91	12.46	7.70	4361	37561	31150	0.83
	Tower-20	400	445	20	8.9	12	94.93	8.90	5.50	3115	26829	22250	0.83
	Tower-21	400	445	20	8.9	12	94.93	8.90	5.50	3115	26829	22250	0.83
Workshop													
	Tower-12	400	445	20	8.9	12	94.93	8.90	5.50	3115	26829	22250	0.83
Main/RMG													
	Tower-3	400	445	36	16	12	170.88	16.02	9.90	5606	48293	40050	0.83
	Tower-4	400	445	36	16	12	170.88	16.02	9.90	5606	48293	40050	0.83
	Tower-5	400	445	36	16	12	170.88	16.02	9.90	5606	48293	40050	0.83
	Tower-16	400	445	20	8.9	12	94.93	8.90	5.50	3115	26829	22250	0.83
	Tower-17	400	445	20	8.9	12	94.93	8.90	5.50	3115	26829	22250	0.83
	Tower-18	400	445	20	8.9	12	94.93	8.90	5.50	3115	26829	22250	0.83
	Tower-19	400	445	20	8.9	12	94.93	8.90	5.50	3115	26829	22250	0.83
Admin													
	Tower-1	400	445	36	16	12	170.88	16.02	9.90	5606	48293	40050	0.83
	Tower-2	400	445	36	16	12	170.88	16.02	9.90	5606	48293	40050	0.83
	Tower-6	400	445	28	12.5	12	132.91	12.46	7.70	4361	37561	31150	0.83
	Tower-7	400	445	28	12.5	12	132.91	12.46	7.70	4361	37561	31150	0.83
	Tower-8	400	445	36	16	12	170.88	16.02	9.90	5606	48293	40050	0.83

Table A6.1 RTGC #3 logbook data on HSD filled & operating hours between March 1-20, 2003

Date	*Operating hours (hrs)*	*HSD consumed(L)*	HSD consumption rate (L/hr)
March 1	22	340	15.5
2	23	N. A.	N. A.
3	23	508	22.1
4	15.45	649	42.0
5	12.45	304	24.4
6	21.1	329	15.6
7	23	480	20.9
8	23	442	19.2
9	23	N. A.	N. A.
10	23	609	26.5
11	22.3	440	19.7
12	22.05	430	19.5
13	22.30	460	20.6
14	23	424	18.4
15	21.15	236	11.2
16	23	N. A.	N. A.
17	15.15	523	34.5
18	21	510	24.3
19	23	476	20.7
20	20.45	N. A.	N. A.
Total	**422.4**	**7160**	

N. A – Not available

Annexure 6.2



V. AUTOMAT & INSTRUMENTS (P) LTD.
ISO-9002 CERTIFIED COMPANY

ISO-9002 Certified From RVA Holland
Accredited by the Dutch Council for Accreditation

Automat
... the level & gas people

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26817258, 26817820
Fax 91-11 26819410
E-mail vautomat@vsnl.com
website www.automatindia.com

[illegible]/03/03-04
[illegible] May [illegible]

To,
The Container Corporation of India Ltd
[illegible] Depot
[illegible]
New Delhi

Kind Attn. : Mr. K. [illegible] Gen. Manager (Tech.)
Sub : [illegible] Level [illegible] Gauges

LEVEL ✦ FLOW

PRESSURE ✦ GAS

Dear Sir,
This is to thank you for the courtesy extended to Mr. S. Chhabra and undersigned when they visited your depot on [illegible]. As discussed we are pleased to submit our most competitive offer as under :

1. For the Diesel Tank of the Crane
Transmitter and Panel and One no. Reflex Level gauge for visual and direct [illegible] mounted [illegible] tank
PRICE :- Rs.29,500.00 each ex works N Delhi (Transmitter will be top mounted on tank & C to C side mounted)
ALTERNATIVELY Magnetic Level Indicator with Transmitter and Panel for visual indication at the Tank and indication on the Panel
PRICE :- 30,350.00 each. Ex works N Delhi (C to C as 350mm in both cases)

2. Magnetic Level Indicator for, with Transmitter for visual indication on Diesel tank and indication on Panel (For the Tank Mounted in the Truck) Gauge is side Mounted on tank, C to C 1250mm approx
PRICE :- Rs.35,500.00 each ex works N Delhi

The prices offered above are only for supply and fixing of the Transmitter/Gauges is not in our scope. However we will help with supervision only of the said work whenever required

We shall be requiring the drawings of the Tank of the Crane to decide the C to C distances

The Panel will consist of
1. Hooter
2. Digital level indication & alarm set [illegible]
3. L.E.D. indication of [illegible]

BARODA
[illegible]
[illegible] Circle
Opp. S.T. [illegible] Office
Baroda - 390 [illegible]
Ph. 2432347, 2351312
Fax [illegible]
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MUMBAI
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Ph. 25535110, 25570677
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E-mail vautomatmum@vsnl.net

EASTERN REGION
[illegible] Executive Centre
8, Acharya J.C. Bose Road,
Kolkata - 700017
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CHENNAI
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D 14, Basement Nelson
Manickam Road, Aminjikarai,
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SECUNDERABAD
425, 3rd Floor, Bhavyas Padmavathi
Plaza Commercial Complex,
Bhagya Nagar Society Opp. KPHB
Colony, Behind KPHB Bus Stop
Secunderabad - 500 872
Ph. 306 [illegible] Telefax 040 3062151
E-mail vautomat@[illegible].com

... the best [illegible]

CON[illegible] [illegible]

[illegible]
[illegible]

[illegible]

[illegible]

[illegible]

Yours Sincerely
for V [illegible] & [illegible] Pvt. Ltd

[illegible]

Table A6.3 Engine loading (%) details of two DG sets

					Set #4			
Sl. no	Time (hrs)	Set #1	Time (hrs)	Set #2	Time (hrs)	Without capacitor	Time (hrs)	Without capacitor
1	12:15	41.6	14:30	65.1	16.30	55.5	17.05	62.97
2	12:20	54.0	14:40	44.9	16.35	54.4	17.15	62.47
3	12:25	60.3	14:50	44.9	16.40	55.2	17.25	61.45
4	12:30	60.3	15:00	40.4	16.45	54.8	17.35	62.47
5	12:40	60.3	15:10	44.9	16.50	54.7	--	--
6	12:45	69.6	15:25	44.9	16.55	55.2	--	--
7	12:58	69.6	--	--	17.00	55.0	--	--
8	13:05	67.3	--	--	--	--	--	--
9	13:15	67.3	--	--	--	--	--	--

Table A6.4a SEGR for DG set #1

Month	Units generated (kWh)	Operational hours (Hrs)	HSD consumption (litres)	SEGR (kWh/l)
January 2002	4960	16.8	1758	2.82
February	320	11	120	2.67
March	3760	12.9	1352	2.78
April	4200	12.4	1328	3.16
May	2800	9.9	973	2.88
June	5720	25.5	1962	2.92
July	12000	38.7	3877	3.10
August	6160	19.9	2055	2.99
Sept.	13280	42.3	4272	3.11
October	7520	23.7	1911	3.94
November	2080	5.9	656	3.17
December	4880	13.6	1657	2.95

Table A6.4b SEGR for DG set #2

Month	Units generated (kWh)	Operational hours (Hrs)	HSD consumption (litres)	SEGR (kWh/l)
January 2002	1480	5.6	98.93	2.67
February	560	1.8	122.7	2.53
March	600	30	114.66	1.75
April	1480	7.3	107.26	1.89
May	1840	7	89.42	2.94
June	7520	27.7	92.5	2.93
July	9400	53.7	55.61	3.15
August	4400	25.9	67.8	2.50
Sept.	7160	42.4	69.83	2.42
October	7520	34.8	73.82	2.93
November	1040	6.1	70.82	2.41
December	2640	14.8	66.7	2.67

Annexure 8.2

Inspection and Planned Maintenance Instruction (Air compressor)

1. The entire unit, motor, compressor, receiver and mountings should be inspected for any sign of deterioration or corrosion. Ensure all items are intact and in a good state of repair.
2. Intake air filter (3 months)
3. Compressor for air or oil leaks
4. Tighten bolts
5. Oil level
6. Oil change (3 months)
7. Belt tension (alignment, condition)
8. Sheave wear
9. Grease (repack motor annually)
10. Lubricate motor (oil) – 3 months
11. Check motor shaft for excess end play (3 months)
12. Cylinder relief valve
13. After cooler (drain). Check water out temperature
14. Safety relief valve, all check valves
15. Drain receiver
16. Electric wiring (voltage, amps)
17. Motor starter and terminal connections not loose or burnt
18. Any strange knock or rattles
19. All piping, valves (hand, electrical or pneumatic)
20. Pressure control switch
21. Gauges
22. Area under and around compressor is clean, dry and clear of obstructions